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GENETICS AND VARIETY IMPROVEMENT

Inheritance of the Number of Flowers in Flower Clusters of Beta Vulgaris L.

V. F. SAVITSKY[1]

The monogerm character, which is now being utilized in breeding work with sugar, fodder and table beets in America and in western Europe, originated from the line SLC 101 mm (4)[2]. A single basic recessive gene *m* is responsible for this character. Some other genes may modify the expression of the gene *m*, causing the appearance of a few "double-germ" fruits on monogerm plants (5).

The present paper is devoted to a study of inheritance of the number of flowers in a flower cluster of *Beta vulgaris* L. and is limited to an analysis of genetical phenomena brought about by action of the basic genes. The term monogerm refers to one flower and only one germ for each fruit, whereas the term multigerm refers to two or more flowers or possible germs for each compound fruit or flower cluster (usually referred to here as the "cluster"). This flower cluster in multigerm beets on maturity becomes the seed ball (2).

Materials

Due to the self-fertility of SLC 101 *mm*, all F_1 hybrids with this line were found to be self-fertile. The self-fertility was retained in subsequent generations because all F_1, F_2, etc., hybrids were obtained through selfing (1 and 3).

The hybrids studied originated from crosses of the monogerm beet SLC 101 *mm* with different multigerm races of sugar, fodder and table beets.

Methods

F_1 hybrids were obtained by exchanging pollinating bags. Some of the hybrids were obtained after emasculation and controlled pollination.

All F_1 hybrids originated from crosses between two separate plants. The F_2 or F_3 hybrids originated from selfing single F_1 or F_2 plants. For analyzing a large number of individuals from the same cross, several hybrid families were planted separately.

To count the number of flowers in a cluster, seeds from each F_1, F_2, or F_3 plant were harvested separately. In determining the number of seeds in a seed ball, a test sample consisting of 100 seed balls was used.

Data for only a part of the hybrids studied are presented in this paper.

Phenotypic Variation in the Number of Flowers in a Flower Cluster of a Homozygous Multigerm *(MM)* and a Heterozygous Multigerm *(Mm)* Beet

Monogerm beets grown under different environments remain monogerm, but the size of fruit varies. The size of fruits in multigerm beets also varies under different conditions. In multigerm beets, the change consists in a variation in the size of individual flowers in a seed ball as well as in their number. This complicates the genetic study of this character.

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[1] Collaborator, Agricultural Research Service, Field Crops Research Branch, U. S. Department of Agriculture, in cooperation with the Beet Sugar Development Foundation.

[2] Numbers in parentheses refer to literature cited.

Table 1.—Variation of Number of Flowers in the Flower Cluster in F_1 Hybrids Between Monogerm and Different Multigerm Beets.

Generation	Origin	Monogerm beets	Number of multigerm plants and degree of multigerm condition — Degree of multigerm condition, number of flowers per 100 flower clusters as follows: 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330 340 350	No. multigerm plants	Analysis (excluding *mm* class) on flowers per 100 clusters: Mean	S.D.	C.V.	S.E.M.
S_0 Population	SLC 101 *mm*	1						
	SL 92		6 8 8 6 5 2 5 3 1 1 1 1 1	1	49	228.6	35.00	15.3	5.00
	Crosses of monogerm beets with multigerm populations							
F_1	SL 92 x SLC 101 *mm*		1 1 8 9 11 16 5 3 1 2		57	192.6	19.23	10.0	2.55
F_1	SLC 101 *mm* x SL 824		1 2 1 5 2 4 3 3 1 1 1		24	197.1	25.60	13.0	2.65
F_1	Egyptian x SLC 101 *mm*		1 1 2 3 4 4 1 1 1		18	188.3	22.29	11.8	5.26
	Crosses of monogerm beets with different multigerm lines							
F_1	04 x SLC 101 *mm*	3	4 2 2 3 13 4		31	166.1	22.00	13.2	3.95
F_1	9524-2-92 x SLC 101 *mm*		1 1 3 4 1		10	181.0	15.23	8.4	4.81
F_1	9529-2 x SLC 101 *mm*		3 21 4 4 1		33	193.6	9.29	4.8	1.62
F_1	MM Peragis x SLC 101 *mm*		1 5 5 1 4 1 3 3		23	213.5	23.47	10.9	4.89

There is a variation in the number of flowers in the flower cluster of individual multigerm plants. Even the flower cluster from the same inbred line or from the same clone contains a variable number of flowers.

Variation in the number of flowers in a cluster follows a peculiar pattern for each genotype. Races which have only a few flowers in a flower cluster usually produce only monogerm or double-germ fruits. Races with highly multiple fruits have 2, 3, 4 and 5 flowers per cluster. The number of monogerm fruits found among them was very small.

Similar variability in the number of flowers in a cluster can be observed in multigerm homozygous (*MM*) beets as well as in heterozygous beets (*Mm*). In many instances the fruits of heterozygous plants (*Mm*) differ from the multigerm homozygous parent only by a larger percentage of monogerm fruits.

First Generation Hybrids

The most common biotypes of the multigerm beet SL 92 (a selection from the curly-top-resistant variety U. S. 22/3) are those with 200-250 flowers per 100 flower clusters. The average number of flowers per cluster in the individual biotypes from this variety varied from 190 to 350 per 100 flower clusters (Table 1). Certain beet varieties have races wtih either a greater or a smaller number of flowers in a cluster.

The F_1 hybrids from crosses between multi- and monogerm beets have a smaller number of flowers in a cluster than those of the multigerm parent (Table 1). Nevertheless, the number of flowers per cluster in the different F_1 hybrid combinations fluctuated greatly (from 140 to 250 flowers per 100 flower clusters).

A study of F_1 hybrids obtained by crossing recessive monogerm beets with different multigerm plants belonging to the same variety can be regarded as an analysis ofthe gametes in this multigerm population. In this manner it is possible to show clearly the differences in genetic make up of individual populations. For example, all F_1 hybrids originating from crosses of monogerm beets with certain multigerm populations of the sugar or fodder beets were characterized by a greater variability in the number of flowers in a cluster than other F_1 hybrids to different multigerm genotypes (for example, a clone or individuals). This proves that varieties of the sugar beet are made up of many genetically different races in regard to number of flowers per flower cluster.

First Back-Cross Generaton

In the b_1 generation when a monogerm beet is backcrossed to an F_1 *Mm* hybrid, 50 percent monogerm *mm* and 50 percent heterozygous multigerm *Mm* plants segregated out (5).

Multigerm plants which originate from different backcrosses are found to be different in regard to number of flowers in a cluster (Table 2).

The variability of the number of flowers in a cluster as it occurs in multigerm plants belonging to different backcross combinations also changes. Backcrosses which originate from crosses with populations have a wider range of variability than backcrosses produced from a cross between only two genotypes (Table 2).

Table 2.—Variation of Number of Flowers in the Flower Cluster of Male-Sterile Backcross Hybrids.

Generation	Origin	Monogerm beets	Number of multigerm plants and degree of multigerm condition: Degree of multigerm condition, number of flowers per 100 flower clusters as follows: 110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	No. multigerm plants	Analysis (excluding monogerm class) on flowers per 100 clusters: Mean	S.D.	C.V.	S.E.M.
Crosses of monogerm beets with multigerm populations																							
F_1	*MM* x SLC 101 *mm*			3		5	5	6	13	34	47	30	13	11	3	6	4		180	190.6	30.79	16.15	2.29
b_1	(*MM* x SLC 101 *mm*) x 101 *mm*	43	2	3	1	5	5	3	2	6	7	5	1	2	1		1		44	170.9	33.25	19.46	5.02
Crosses of different monogerm hybrid lines with heterozygote Mm																							
b_1	*Mm* (9333. SLC 101 *mm*) x N 769 mm	9							2	5	2								9	180.0	7.07	3.93	2.36
b_1	*Mm* (9333. SLC 101 *mm*) x 766 *mm*	7							1	2	6								9	185.6	7.27	3.92	2.42
b_1	*Mm* (9563. SLC 101 *mm*) x 9544-1-3 *mm*	8				1		1	1	3	3								9	175.6	16.67	9.49	5.56
Crosses of heterozygous *Mm* beets with multigerm homozygous *MM*																							
b_1	(MM x SLC 101 *mm*) x *MM*												5	7	8	7	2	2	31	230.0	14.14	6.15	2.54

Crosses Between the Monogerm Beet and Races Which Have a Small Number of Flowers in a Cluster

The inbred line SLC 100 has both mono- and double-germ seed balls. A plant with an average of 172 flowers per 100 flower clusters was taken for crosses representing this line.

Hybrids between the "few-germed" line SLC 100 and the monogerm beet SLC 101 are of interest because this type of segregation differs from that obtained from most of the hybrids between monogerm and multigerm beets.

Usually F_2 populations obtained from crosses between monogerm and multigerm beets are easily divided into two groups, one that includes only monogerm plants and another group in which all plants have multi-germ seed balls.

The F_2 hybrid from a cross between the "few-germed" line SLC 100 and the monogerm beet SLC 101 *mm* showed segregation for monogerm and double-germ fruits (Table 3). Some of these F_2 plants were intermediate with 110, 120, 130, etc., flowers per 100 flower clusters. For this reason it is difficult in these particular populations to classify individuals for mono- or multigerm fruits.

The absence of distinct boundaries between separate genetical classes in F_2 hybrid plants is typical in the segregation of hybrids for quantitative characters. Quantitative characters are usually conditioned by the action of many genes. The F_2 frequency curves are often more or less regular and symmetrical and have but one principal mode.

The F_2 frequency curve for the hybrid from SLC 100 $\times$ SLC 101 *mm* is bimodal. One mode is formed by the monogerm types. The other mode is located on the opposite end of the curve and corresponds to the multigerm parent. Between them are located the different intermediate forms (Table 3).

Three kinds of F_2 segregates were selfed and their progeny (F_3 lines) were studied in 1953. The progeny from F_2 monogerm plants produced, as always, monogerm F_3 lines which did not segregate (Table 3). The progeny from F_2 plants which had the greatest number of flowers in a flower cluster (172 flowers per 100 clusters) also did not segregate but consisted of plants which had predominantly double-germ fruits. The progeny from F_2 plants which had an intermediate number of flowers in a cluster (134 flowers per 100 clusters) was found to be heterozygous and gave the same segregation as observed in the original F_2 population. In the offspring from this hybrid, F_3 or F_4 lines, there were no plants with three- or many-flowered clusters.

The monogerm SLC 101 *mm* was also crossed with another "few-flowered" race, G.W. 4821, received from Dr. H. E. Brewbaker of the Great Western Sugar Company. The average number of flowers in this race is approximately 180-190 per 100 clusters. The F_1 hybrid from G.W. 4821 and SLC 101 *mm* had only mono- and double-germ fruits in varying proportions. In F_2 a segregation occurred for plants with monogerm (about

Table 3.—Variation in Number of Flowers per Flower Cluster in F_2 and F_3 Hybrids Between Monogerm and "Few-Flowered" Multigerm Beet Rraces.

Generation	Origin	Monogerm beets	Number of multigerm plants and degree of multigerm condition. Degree of multigerm condition, number of flowers per 100 flower clusters as follows: 110	120	130	140	150	160	170	180	190	200	210	220	No. multigerm plants	Analysis (excluding monogerm class) of flowers per 100 clusters: Mean	S.D.	C.V.	S.E.M.
																		Percent	
	Crosses, SLC 100 x 101 *mm*																		
P	SLC 100 "few-germed" multigerm								1						1[1]				
P	SLC 101, pure monogerm	1																	
F_1	SLC 100 x SLC 101 *mm*							1							1[1]				
F_2	SLC 100 x SLC 101 *mm*	8	3	4	1	2	3	4	7	4	2				30	153.3	25.37	16.54	4.63
F_3	N 241: monogerm progeny	21																	
F_3	N 242: from F_2 plant, 172 flowers per 100 clusters								2	4	17				23	186.5	6.47	3.47	1.35
F_3	N 243: from F_2 plant, 134 flowers per 100 clusters	12		1	1	2	2	3	9	5	5				28	167.0	18.98	11.37	3.96
	Crosses, G.W. 4821 x SLC 101 *mm*																		
P	G.W. 4821									1					1[1]				
F_2	G.W. 4821 x SLC 101 *mm*	17		1		8	3	9	2	6	10	3	2	3	47	173.0	25.27	14.61	3.67
	Crosses, G.W. 4821 x SLC 100																		
F_2	G.W. 4821 x SLC 100			1	1		2	2	2	7	7	1	1	1	25	177.2	12.64	7.13	2.53

[1] Frequency distributions not shown for parental lines or F_1 hybrid.

25 percent) and double-germ fruits (Table 3). Plants with an intermediate number of flowers in a cluster were also observed. The latter had from 120 to 170 flowers per 100 clusters. The type of plants which had about 110 flowers per 100 clusters was absent in this hybrid. Therefore, the monogerm-recessive plants in this F_2 hybrid did not overlap with plants which had "few-germed" clusters. However, in this hybrid the distinction between monogerm and "few-germed" types is still very slight. Plants with three-germed flower clusters in F_2 and F_3 were not observed in offspring from this hybrid.

Crosses of "Few-Germed" Races with Each Other

The "few-germed" inbred line SLC 100 was crossed with the "few-germed" race G.W. 4821. The F_1 hybrid had flower clusters consisting of a small number of flowers per flower cluster, about 170-180 per 100 clusters. In F_2 this hybrid segregated for "few-germed" forms (Table 3), but monogerm plants and plants with three-flowered clusters were absent.

Among the "few-germed" F_2 plants, the individuals with the smallest number of flowers per cluster produced about 72 percent monogerm fruits.

The same type of races, and even races with few-flowers per cluster, were obtained by continuous selection for a number of generations within limits of the original inbred line SLC 100. Such "pseudo-monogerm" lines showed a very great variability with regard to number of flowers in a cluster. This phenomenon was observed not only on plants grown under different conditions (for example, in greenhousees during the winter and in the field during the summer), but also on different branches of the same plant, if these branches had been formed at different seasons of the year. With the true monogerm *mm* beet such variability was never observed.

Crosses of the Monogerm Beet with the More Common Type of Multigerm Beet

Seed collected from a single plant in ordinary multigerm varieties has 2, 3, or 4 germs per seed ball. In these races the average number of flowers in a flower cluster varies from 200 to 250 per 100 clusters (Table 1).

When this type of beet is crossed with SLC 101 *mm*, F_2 populations show a well-defined monohybrid type of segregation for the monogerm-recessive and the multigerm-dominant forms. These two classes are quite distinct because individual flowers numbering 110-150 per 100 clusters are absent. Table 4 gives frequency curves for six of these F_2 hybrids from the crosses of SLC 101 *mm* with the more common types of multigerm beets which occur in sugar, fodder or table beet varieties. The bimodal F_2 curves observed in hybrids between SLC 101 *mm* and the "few-germed" beet is also characteristic of F_2 hybrids between mul tigerm and monogerm beets.

The average number of flowers per cluster in multigerm segregates which occur among F_2 hybrids derived from crosses between monogerm and ordinary multigerm beets was greater than in F_2 segregates produced from a cross between monogerm and "few-germed" beets. However, the amplitude of variation for the number of flowers per flower cluster for the multigerm segregates remains almost the same for both types of F_2 hybrids. This is

Table 4.—Variation of Number of Flowers in the Flower Cluster in F_2 Hybrids Between Monogerm and Multigerm Beets.

Generation	Origin	Monogerm beets	Number of multigerm plants and degree of multigerm condition: Degree of multigerm condition, number of flowers per 100 flower clusters as follows: 110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	270	No. multigerm plants	Analysis (excluding *mm* class) on flowers per 100 clusters: Mean	S.D.	C.V.	S.E.M.
Crosses between mono- and "few-germed" multigerm beets																								
F_2	SLC 100 x SLC 101 *mm*	8	3	4	1	2	3	4	7	4	2									30	153.3	25.37	16.55	4.63
F_2	G.W. 4821 x SLC 101 *mm*	17		1		8	3	9	2	6	10	3	2	3						47	173.0	25.27	14.61	3.69
Crosses between mono- and multigerm beets																								
F_2	Janash 9333 x SLC 101 *mm*	19						1		5	16	19	5	2						48	195.6	10.90	5.57	1.57
F_2	Oberndorf 9567 x SLC 101 *mm*	10						1	1		2	13	6	3	3					29	204.1	15.47	7.58	2.87
F_2	SLC 101 *mm* x SL 824	13						1	5	8	20	8	2	1						45	188.7	11.79	6.25	1.76
F_2	SL 92 x SLC 101 *mm*	12						2	1	3	4	6	1	2						19	191.6	17.08	8.91	3.92
F_2	Mammoth 9565 x SLC 101 *mm*	6					1		4	2	4	2	2							15	184.7	16.85	9.12	4.35
F_2	Egyptian x SLC 101 *mm*	19						1	1	4	12	4	6	3	3	1	1			36	200.8	19.91	9.92	3.32
Crosses between mono- and highly multigerm beets																								
F_2	ZZ R. and G. x SLC 101 *mm*	9										3	7	3	2	2	3	3	1	24	227.9	22.26	9.77	4.54

due to the fact that hybrids from crosses with "few-germed" plants do not segregate for types with as many flowers per cluster and hybrids from crosses with highly multigerm beets do not segregate for "few-germed" types.

Some races of the sugar beet, and especially of the fodder beet, have seedballs with a very large number of germs (300 flowers per 100 clusters). In such races fruits occur which often contain more than five or six flowers per cluster.

Segregation in F_2 hybrids obtained from crosses between SLC 101 *mm* and races of similar highly multigerm types follows the pattern of the monohybrid scheme (Table 4). Differences in number of flowers per cluster between monogerm and multigerm segregates among F_2 hybrids in this case are even greater because, in spite of the striking differences between the two parental forms, the F_2 hybrids have no intermediate forms. The bimodal character of the frequency curves becomes even more apparent in this case, and the amount of variation for the number of flowers per cluster of multigerm segregates remains the same.

Discussion

F_1 Hybrids

The multigerm character is not completely dominant over the monogerm character. For this reason F_1 hybrids, on an average, have fewer flowers per flower cluster than that of the multigerm parent. When a monogerm beet is crossed with races of multigerm beets which have different numbers of flowers in a cluster, the different F_1 hybrids will have a different number of flowers in their flower clusters. The difference in the number of flowers per cluster in F_1 hybrids from crosses between mono- and multigerm beets depends on the number of flowers per cluster in the multigerm parent.

Differences in number of flowers per flower cluster observed among different F_1 hybrids are shown also in the corresponding F_2 hybrids. These differences can be observed only in the multigerm segregates in the F_2 generation.

F_2 Hybrids

All F_2 hybrids from crosses between a monogerm beet and "few-germed" or multigerm types of sugar, fodder or table beets had the following general characteristics:

1. All F_2 hybrids segregated according to the monohybrid scheme. The number of flowers in the flower cluster of the multigerm parent did not affect the percentage of the recessive monogerm plants recovered.

2. Monogerm lines obtained from the most diverse F_2 hybrids and propagated for several generations never segregated for multigerm types. They retained their monogerm character also when they were crossed with each other. Self-pollination of multigerm F_2 plants produced F_3 lines, some of which were constant in their multigerm plants just as in the F_2 generation.

Monogerm plants were never recovered from crosses of "few-germed" plants to multigerm beets.

3. The frequency curves were bimodal. One mode is made up of monogerm plants and the other by multigerm plants. These two modes are found to be close to each other in F_2 hybrids from crosses between monogerm and "few-germed" beets. In F_2 hybrids between multigerm and monogerm beets, two modes are well separated from each other. Overlapping in the number of flowers in a flower cluster between mono- and multigerm beets is completely absent in such hybrids.

F_2 hybrids between monogerm and "few-germed" beets do not segregate for highly multigerm types. F_2 hybrids between monogerm and ordinary multigerm beets do not segregate for "few-germed" beets.

When "few-germed" races of beets were crossed with each other neither monogerm nor highly multigerm plants were obtained.

Any hybrid between monogerm and multigerm beet gave only monohybrid segregation. The segregates consist of only two parental types. The plants of new types never appeared. For this reason in the multigerm segregates in F_2 hybrids obtained from crosses between mono- and multigerm beets, the coefficient of variation and the amplitude of variation for the number of flowers in a flower cluster was not higher than in "few-germed" segregates in F_2 hybrids between monogerm and "few-germed" beets.

The coefficient of variation and the amplitude of variation for number of flowers per flower cluster of multigerm segregates does not change in F_2 hybrids, depending on an increase in number of flowers per flower cluster of the multigerm parent. But the average number of flowers per cluster of the multigerm segregates which appear in different F_2 hybrid combinations were quite different and depended on the number of flowers per cluster in the multigerm parent.

Although the number of flowers in a cluster constitutes a typical quantitative character, the inheritance does not correspond to the theory of multiple factors (polymeric genes). Multiple factors inheritance is based on several genes which belong to different alleles. Consequently, the different hybrids for the same character segregate sometimes as monohybrids, sometimes as dihybrids or as polyhybrids.

When the differences for any quantitative character increase, the number of genes determining these differences increase at the same time. The segregation in F_2 is more complicated and the diversity of segregating plants increases. The value of the coefficient of variation also increases. Such appearances were not observed in the hybrids studied.

The coefficient of variation and number of flowers per cluster of multigerm segregates does not change in F_2 hybrids depending on increase in number of flowers per cluster of the multigerm parent. But the average number of flowers per cluster of the multigerm segregates which appear in different F_2 hybrid combinations were quite different and depended on the number of flowers per cluster in the multigerm parent.

The types of segregation in the hybrids studied could not be explained on the basis of the multiple factor hypothesis. To make this obvious the data obtained on segregation for the number of flowers per flower cluster was compared with the values which could be expected if the segregation of hybrids was controlled by several multiple factors.

Table 5.—Segregation for Multigerm and Monogerm Plants in F_2 Hybrids.

Origin		Monogerm beets	Number of multigerm plants and degree of multigerm condition. Degree of multigerm condition, number of flowers per 100 flower clusters as follows: 110	125	140	155	170	185	200	215	230	245	260	No. multigerm plants
	Expected		0.02	0.23	1.05	2.81	4.91	5.87	4.91	2.81	1.05	0.23	0.02	24
	Expected		1	10	45	120	210	252	210	120	45	10	1	1024
ZZ R. and G. x SLC 101 *mm*	Observed	9							6	7	3	4	4	24
	Expected		0.7	6.0	21.0	42.0	52.5	42.0	21.0	6.0	0.7			192
	Expected		1	8	28	56	70	56	28	8	1			256
Multigerm x SLC 101 *mm*	Observed	79			1	6	23	69	63	22	7	1		192
	Expected		0.7	4.4	11.0	14.7	11.0	4.40	0.7					47
	Expected		1	6	15	20	15	6	1					64
G.W. 4821 x SLC 101 *mm*	Observed	17		1	9	11	5	13	4	4				47
	Expected		1.87	7.48	11.22	7.48	1.87							30
	Expected		1	4	6	4	1							16
SLC 100 x SLC 101 *mm*	Observed	8	5	3	3	6	9	4						30

Insofar as monogerm plants segregated as a simple recessive (*mm*) in F_2 of all hybrids independent of the number of flowers per flower cluster of multigerm segregates, it could be supposed: 1. that all multigerm plants carried gene *M*, and 2. that multiple factors ($C_1C_2C_3C_4$ and C_5) controlled the number of flowers in the flower clusters of the multigerm plants.

In such case the genotypes of the parental plants would be as follows:

SLC 101 mm	mm c_1c_1 c_2c_2 c_3c_3 c_4c_4 c_5c_5
SLC 100	MM C_1C_1 C_2C_2 c_3c_3 c_4c_4 c_5c_5
G.W. 4821	MM C_1C_1 C_2C_2 C_3C_3 c_4c_4 c_5c_5
Common types of multigerm beets	MM C_1C_1 C_2C_2 C_3C_3 C_4C_4 c_5c_5
R. and G. ZZ Variety	MM C_1C_1 C_2C_2 C_3C_3 C_4C_4 C_5C_5

In Table 5 the data obtained for segregation are compared with the values expected according to the hypothesis of multigerm factors for the majority of hybrids. The observed numbers do not agree with the expected ones. Statistical evaluation of these data showed that the hypothesis of multiple factors could not explain the observed type of segregation in hybrids studied. The disagreement between observed and expected values could not be decreased also by the assumption that the segregation was controlled by higher or lower number (4 or 6-7) of multiple factors.

Therefore, it is more probable that genetical differences in any of these hybrids were caused by different genes from the same allele, than by different number of multiple factors. The hybrids which have been analyzed include the members of the multiple allele listed in Table 6.

Table 6.—Designation of Genes in the Multiple Allele *M-m*.

Designation of member of multiple allele	Name and origin of varieties or lines in which a given gene has been found
Symbol	
mm	Inbred line SLC 101 *mm* which bears monogerm fruits.
M^1 M^1	Inbred line SLC 100. This line has fruits with few germs. Isolated from the same population, "Hybrid 18 Michigan," in which the SLC 101 *mm* was found.
M^{Br} M^{Br}	Inbred line G.W. 4821, which has double-germ fruits.
M M	A gene or a number of related genes occurring most frequently among various multigerm varieties of the sugar, fodder, or table beet. Has an "average" number of flowers (close to three) in flower cluster.
M^s M^s	A gene which determines the presence of a large numbr of germs in a seed ball. Isolated from variety Kleinwanzleben ZZ. This gene probably occurs in many varieties of beets.

The beet also includes a number of genes which modify the effect of the above mentioned basic gene. The gene modifiers are not allelic to the *m-M* alleles. They are not discussed in this article, nor is the problem of compounds for the *M-m* allele.

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Relation Between the Weight of Fruit and Weight of Germ in Mono- and Multigerm Beets

V. F. Savitsky[1]

Introduction

The quantity of monogerm seed planted per acre must not be large and must not surpass the quantity necessary for normal beet stands to avoid hand thinning. At the same time, the planting must have a normal stand of desirable thickness. To provid for a good proportional stand, the monogerm seeds must have good germinating ability and give strong vigorous seedlings. Improvement of seed quality has not been successful in previous breeding work because it is impossible to breed for this character in multigerm beets, but now the improvement of beet seeds becomes a real possibility because of the presence of monogerm beets.

Selection for size of fruit requires knowledge of the interrelationship between the weight of the fruit and the weight of germ produced within it. The beet seed is surrounded by hardened pericarp tissue and it is difficult to take it out without damage. It was necessary to work out a method which would permit taking out the seeds from the fruits without injury.

Method

Different methods of treatment of fruits were studied. The best results were obtained by a method of hydrolysis with hydrochloric acid. For this purpose 100 fruits were placed in a test tube filled with a solution of hydrochloric acid and held in an oven at 50° C. for eight hours. The concentration of hydrochloric acid applied was 4 to 5 percent. After the acid treatment the fruits were rinsed in water for three minutes and placed again in the oven to dry at 45-50° C.

The germs were removed from the fruits after shaking the small paper envelopes in which they were enclosed or by crushing the pericarps by light knocks with a flat hammer. The fruits were placed between two layers of thin cloth for crushing.

Investigation of all samples must be conducted under the same conditions. Precautions must be taken not to keep the fruits too long in hydrochloric acid, and in applying higher temperatures. Under such conditions the process of hydrolization may go too far and the germs may be damaged. High temperatures must be avoided also when the fruits are dried. Temperatures which are too high may destroy the organic substances of the germs or they may even be burned. The ovary in beet fruits sometimes contains two ovules instead of one, or two embryos can develop from two embryo sacs in the same ovule (5)[2]. Such twin germs and germs with two embryos differ in shape from ordinary germs. They were excluded from these experiments.

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[2] Numbers in parentheses refer to literature cited.

Material

Seventy F_3 and F_4 monogerm inbred lines obtained from hybridization of SL 101 *mm* with different American and European multigerm varieties were involved in the investigations. The fruits from monogerm and multigerm plants were compared within the same F_2 hybrid populations obtained from crosses of SL 101 *mm* with multigerm sugar beets and also in different MS backcross hybrids.

The majority of cytoplasmic male-sterile lines used in these investigations were selected in hybrids derived from crosses of male-fertile sugar beet varieties to SL 101 *mm*.

Experimental Results

Interrelation Between Number of Flowers in the Flower Cluster and Weight of Fruits and Germs.

In multigerm sugar beet populations the size of the seed ball increases with the number of flowers in the flower cluster (7), whereas the average weight of single flowers in the cluster decreases. Parallel with this decrease in the average weight of the flowers, there is also a decrease in the weight of germs (see Table 1).

Table 1.—Weight of 1,000 Germs and Fruits in Single Germ, Double-Germ and Multigerm Fruits from Multigerm Beets.

Hybrid number	Number of flowers in flower cluster of multigerm beets			
	1 flower	2 flowers	3 flowers	4 flowers
	grams per 1,000	grams per 1,000	grams per 1,000	grams per 1,000
Multigerm sugar beet SL 92				
Fruits	10.5	23.6	29.7	36.0
Ave. weight of single flowers	10.5	11.8	9.9	9.0
Germs	1.47	1.59	1.34	1.21
Heterozygous (Mm) Sugar beet				
350 Fruits	12.3	23.0	30.0	
Ave. weight of single flowers	12.3	11.5	10.0	
Germs	2.20	2.16	1.83	
344 Fruits	10.2	22.9	29.1	36.7
Ave. weight of single flowers	10.2	11.4	9.7	9.2
Germs	2.00	2.13	1.83	1.76
345 Fruits	9.6	17.0	26.0	
Ave. weight of single flowers	9.6	8.5	8.8	
Germs	1.85	17.3	16.6	

It must be noted that the individual flowers in one seed ball of multigerm beets contain germs of different weights (1, 3, 4, 9, 10). Small and large germs may be observed in the same seed ball. The larger germs cannot be separated for use as planting material by contemporary methods of segmenting and seed cleaning.

The ordinary multigerm sugar beet varieties sometimes develop single germ fruits at the ends of flowering branches. The flowers located on the ends of branches flower later than the flowers situated in the middle or

at the base of the inflorescence. The fruits which develop at the ends of the branches are always smaller than the fruits at the lower portions of the inflorescence. Therefore, single germ fruits from multigerm beets always have a lower weight than fruits from double-germ or multigerm seed balls.

The same interrelation between the number of flowers in the flower cluster and the weight of fruits, and the germs developed within them, pertains to heterozygous *Mm* plants (see Table 1). In heterozygous *Mm* plants the number of flowers in a flower cluster increases in proportion to the increase in the weight of the fruits. Multigerm fruits from these plants with three and four flowers contain lighter germs than monogerm or double-germ fruits.

Interrelation Between Weight of Fruits and Weight of Germs in Monogerm Inbred Lines

Monogerm inbred lines are distinguished not only by a different shape of fruits, but also by the size of fruits. The weight of 1,000 fruits in monogerm lines with large fruits reached 25-30 grams or more. In lines with small fruits—the weight of 1,000 fruits varied from 6 to 10 grams (see Table 2). The extreme deviation in the weight of 1,000 fruits reached a ratio of 1.3 or a higher ratio in different monogerm lines.

Table 2.—Frequency Distribution Showing Correlation Between Weight of Fruits and Germs in Different Monogerm Sugar Beet Lines.

Weight of 1,000 fruits in grams	Weight of 1,000 germs in grams											
	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75
25												
24											1	
23									1			
22										1		
21									1		1	
20								3				
19							1					
18							1					
17							1		1			
16						2	3	1				
15					2	2	4					
14			2	2	5	1						
13			4	5	6							
12			1		1							
11	1	1	2	3								
10	2	5	2		1							
9		3										
Total Plants	3	9	11	10	15	5	10	4	3	1	2	

A study of germ weight in S_2 and S_3 inbred lines derived from crosses of SL 101 *mm* to different American and European multigerm varieties also showed a large variation in the weight of germs. One thousand germs in lines with large fruits weighed more than three grams. At the same time one thousand germs from the lines with small fruits hardly exceeded one gram (see Table 2).

A study of the interrelation between weight of fruits and germs in the same *mm* lines indicates that both of these characters are closely correlated. When the lines with large fruits are selected, large germs are selected at the same time. The coefficient of correlation between these characters was r = 0.949.

Weight of 1,000 Germs in Monogerm and Multigerm Sugar Beet Plants from the Same F_2 Populations

The fruits of 46 F_2 plants derived from one selfed F_1 plant and grown together in the same field were harvested separately in 1952. This F_2 hybrid originated from crosses of SL 101 *mm* to multigerm sugar beets and consisted of 13 monogerm and 33 multigerm plants (7). The weight of 1,000 fruits and germs was studied separately in each of these plants (see Tables 3 and 4). The fruits of F_2 plants repreesnt F_3 lines. Progenies from multigerm plants had heavier seed balls in comparison with progenies from monogerm plants (see Table 3). The weight of 1,000 fruits in monogerm beets harly reached 81 percent of the weight of fruits in multigerm beets. In spite of this the weight of germs in monogerm progenies proved to be higher than in multigerm segregates. The germs of monogerm plants were 25 percent heavier than the germs from multigerm plants in the same hybrid.

Table 3.—Segregation for Weight of Fruits and Germs in an F_2 Hybrid Between Monogerm and Multigerm Beets.

Weight of 1,000 fruits in grams	Weight of 1,000 germs in grams																
	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6
18								1	2	1							
17																	
16																	
15																	
14							1		2	1	1						
13						2	1	1	2				*1*	*1*			
12						4	1		2	2	1				*1*		
11							1	2				*1*	*1*				
10			1					1	1	*1*	*1*		*1*	2	*1*		
9											1	*1*					
8																	
7									*1*								

[1] The monogerm plants are indicated by italicized figures.

Weight of 1,000 Germs in Mono- and Multigerm Beets in Male-Sterile Backcross Hybrids

The most exact method of establishing the influence of the gene *m* upon the weight of germs consisted in a study of backcross hybrids. Different male-sterile hybrids heterozygous for the gene *m* were pollinated by monogerm beets. The backcross hybrids obtained in this way segregated for mono- and multigerm plants in a 1:1 ratio. Seeds of plants which formed these two classes were harvested and analyzed for their weight. Usually every class consisted of 15 to 30 plants which produced several pounds of seed. The results for weight of seeds in mono- and multigerm beets during 1952-53 are presented in Table 5.

Table 4—Variation of the Weight of Fruits and Germs in Mono- and Multigers Plants In An F_2 Hybrid Between Mono- and Multigerm Beets.

	Weight of 1,000 fruits in grams													Total No.	Average weight	
	6	7	8	9	10	11	12	13	14	15	16	17	18	plants	Grams	Percent
Multigerm plants (MM+ 2Mm)				1	3	3	10	7	5				4	33	12.978 ± 0.40	100.0
Monogerm plants (mm)		1		1	6	2	1	2						13	10.46 ± 0.45	81.2

	Weight of 1,000 germs in grams													Total No.	Average weight	
	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	plants	Grams	Percent
Multigerm plants (MM+2Mm) 1				6	4	5	9	4	4						33	1.724 ± 0.3	100.0
Mongerm plants (mm)							2	1	1	1	3	2	2	1	13	2.161 ± 0.6	125.3

Table 5.—Weight of 1,000 Germs in Mono- and Multigerm Plants in Male-Sterile Backcross Hybrids.

Year	Hybrid No.	Origin of parents: Cytoplasmic *(Mm)* male steriles	*mm* S_3 pollinator	Weight 1,000 germs in grams: Monogerm *mm*	Multigerm *Mm*
1952	50	Janash	SL 92 x SLC 101	2.32	2.12
	49	do.	do.	2.59	2.10
	45	do.	do.	2.75	1.97
	48	U. S. 22/3	U. S. 22/3 x SLC 101	2.40	1.81
	47	Klein ZZ	SL 92 x SLC 101	2.85	2.40
Average weight in grams				2.58	2.08
Average weight in percent				**124.03**	**100.00**
Standard Error in grams				0.10	0.307
1953	79	Janash	SL 92 x SLC 101	2.14	1.58
	80	do.	do.	2.23	1.55
	76	do.	do.	2.30	2.05
	78	Klein ZZ	do.	2.14	2.01
	82	Janash	do.	2.36	1.65
	84	Klein ZZ	do.	2.61	2.16
	89	Janash	do.	2.37	1.70
	87	do.	do.	2.36	1.95
	81	do.	do.	2.95	1.88
Average weight in grams				2.384	1.836
Average weight in percent				**129.8**	**100.00**
Standard Error in grams				0.085	0.074

In backcross hybrids, as well as in F_2 hybrids, monogerm plants produced heavier germs. The increase in weight of germs in monogerm plants over that in multigerm plants was 24 percent in 1952 and 30 percent in 1953.

In Table 6 the weight of fruits and germs is shown in homozygous monogerm plants in comparison with the weight of fruits and germs of single germ fruits developed on multigerm heterozygous *Mm* plants. In all hybrids the fruits from monogerm homozygous plants were larger than the single germ fruits from heterozygous *Mm* plants, and the germs in the fruits of monogerm plants were heavier than the germs from single germ fruits in *Mm* plants.

Table 6.—Average Weight of Monogerm Fruits in Monogerm homozygous Plants and of Single-Germ Fruits Separated from the Seed Balls of Heterozygous *(Mm)* Multigerm Plants in the Same Male-Sterile Backcross Hybrids.

	Monogerm fruits from homozygous monogerm plants		Single-germ fruits from heterozygous plants	
	Wt. in grams of 1,000		Wt. in grams of 1000	
Hybrid No.	Fruits	Germs	Fruits	Germs
350	15.7	2.32	12.3	2.20
345	12.0	2.75	9.6	1.85
344	18.6	2.59	10.2	2.00
Average	15.43	2.55	10.7	2.02
Standard Error	1.90	0.13	0.82	0.10

Conclusion

Germs were taken from the fruits after hydrolysis by hydrochloric acid for analysis of their weight. Increase in weight (also size) of seed balls in multigerm beets was caused mainly by the increase in the number of flowers in the flower cluster, but the average weight of germs decreased as the number of flowers in the flower cluster increased.

In monogerm beets the weight of germs increased in proportion to the size of fruit. This regularity was established by a study of weight of fruits and germs in F_2 populations and in backcross hybrids, as well as in different inbred lines obtained from crosses of monogerm beets to different multigerm varieties. We believe that this is a general regularity for the species *B. vulgaris* L. The multigerm plants which segregated in F_2 generations developed heavier fruits than the monogerm segregates in the same hybrids, but in spite of this the average weight of germs in monogerm plants was higher than in multigerm plants.

The advantage in weight of germs in monogerm beets over that of multigerm beets was also established in male-sterile backcross hybrids.

Thus the breeding of monogerm sugar beets opens up the possibility, not only for production of monogerm varieties, but also for increasing the weight (or size) of the germs themselves.

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Sugar Content in Mono- and Multigerm Sugar-Beet Hybrids, Carrying the gene m Isolated from Michigan Hybrid 18 and the Gene m from Variety U. S. 22/3.

V. F. Savitsky and George K. Ryser[1]

Introduction

The breeding work being conducted now is to substitute multigerm sugar beet varieties with the monogerm ones. The development of monogerm varieties is connected with the introduction of gene *m* into several contemporary multigerm varieties. For this reason it is important to know what changes in sugar content and yield may occur when the gene *m* is incorporated into multigerm populations.

Methods

This problem may be solved by using the ordinary method of genetic analysis in studying F_2 and b_1 hybrids. For this purpose sucrose percent (or dry matter) must be determined in each plant in F_2 or b_1 hybrids, after which they must be planted to observe segregation for type of fruits. Because yield and sugar percentage vary considerably under environmental conditions, it would be necessary to analyze a large number of plants to obtain authentic data. For reasons of economy we could not use this method only.

The other method used consisted of grouping plants according to type of fruits and determination of sucrose percentage in their progeny. The seed was planted in test fields in several replications. To obtain seed for such a test, male-sterile *Mm* plants were polinated with monogerm beets. The progeny of these male-sterile plants segregated into monogerm and multigerm plants which were again pollinated with monogerm beets. The seed from monogerm (*mm*) and heterozygous multigerm (*Mm*) beets was harvested separately in each hybrid combination. By using this method it must be noted that fruits from monogerm male-sterile plants were monogerm and fruits from heterozygous multigerm male-sterile plants had multigerm fruits comprised of germs of two classes, monogerm (*mm*) and multigerm (*Mm*), in the ratio of 1:1 (5)[2].

When such multigerm seed, containing germs of the two genotypes *mm* and *Mm*, is compared with genotypically uniform monogerm seed (*mm*), the action of the gene *M* will be manifest in the average performance of beets obtained from the multigerm seed. However, the effectiveness of the gene *M* will be decreased because of its presence in only 50 percent of the plants.

There were three replications of both mono- and multigerm seed from seven different male-sterile hybrids. Monogerm and multigerm seed was, therefore, compared in a total of twenty-one replications.

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[1] Collaborator and Agent, respectively, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture, in cooperation with the Beet Sugar Development Foundation.

[2] Numbers in parentheses refer to literature cited.

It is possible to determine the influence of genes *m* and *M* upon sugar content in backcross hybrids only when the genes *m* and *M* originated from parental races high in sugar percentage. Male-sterile lines which carried the gene *M* originated from varieties differing in sucrose percentage. These varieties produced normal pollen before they were crossed to SLC 101 *mm*. Male-sterile races were pollinated, in addition to SLC 101 *mm*, by other monogerm self-fertile lines high and low in sugar content.

Use of the Gene m Isolated from Michigan Hybrid 18 and from a Curly-Top-Resistant Variety U. S. 22/3

The monogerm inbred lines used as pollinators were both high and low in sugar content. The monogerm inbred line SLC 101, similar to the majority of the new monogerm lines obtained from crosses with this original monogerm line, was high in sugar. Therefore, it was also necessary to include in the experiment hybrids with low-sugar lines SL 602 *mm* and SLC 609 *mm* which carried in their genotype one gene *m* from the curly-top-resistant strain SL 92 (a selection from the commercial variety U. S. 22/3, very high in curly-top-resistance). From more than a thousand F_1 plants, derived from crosses of SL 92 to SLC 101 *mm*, V. F. Stvitsky found in 1950 an F_1 line consisting of monogerm and multigerm plants. The monogerm plants from this F_1 line remained consistently monogerm in F_2 and F_3 generations. At the same time these monogerm hybrids showed a great diversity of curly top resistance, sucrose percentage and yielding ability in F_3 lines. These lines were used also in the above experiment.

Monogerm plants could occur in F_1 only when the multigerm parent involved in the crosses with SLC 101 *mm* was heterozygous for the gene *m*. In this manner monogerm F_1 plants were obtained which carried one *m* gene from Michigan Hybrid 18 and another *m* gene from SL 92. A study of the constancy of the monogerm character in F_2, F_3 and F_4 generations showed that these two *m* genes did not produce a difference in type of fruit or inflorescence, but the linkage with genes determining sugar content was probably different, as we shall see later.

Experimental Results and Discussion

Sucrose and Yield in Beets Grown from Multigerm and Single-Germ Fruits Collected from Multigerm Plants of the Same Hybrid

In many hybrids multigerm heterozygous *Mm* plants bear multigerm and single-germ fruits. It was important to study both kinds of fruits because their germs contained the same genotype. Therefore, differences in quality of beets would be caused only by differences in the fruits themselves.

Table 1.—Comparison of Beets Grown from Mono- and Multigerm Fruits of the Same Heterozygous Multigerm *Mm* Plants.

Type of fruit	Number replicated plots	Sucrose percent	Na p.p.m.	N per cent	K p.p.m.	Plants per plot	Tons per acre	Lbs. sugar per acre	Percentage basis: Sucrose	Tonnage	Sugar per acre
Multigerm	9	15.56	682	0.30	3688	73.0	23.8	3703	100.0	100.0	100.0
Single germ	9	15.22	704	0.28	3599	69.2	23.6	3592	97.8	99.1	97.0

Such multigerm and single-germ fruits were tested in nine replications (Table 1). No significant differences in sucrose percentage or in tonnage were observed.

Sucrose Percentage in Beets Grown from Multigerm and Monogerm Fruits of Backcross Male-Sterile Hybrids

Experiments conducted with single-germ and multigerm seed (such as the numerous experiments with segmented multigerm seed) give us reason to believe that the mono- or multigerm fruits themselves give no significant change in productiveness of beets. When multigerm beets are substituted for genetic monogerm beets, other characters may be changed because of possible linkage of the gene *m* with other genes. Such linkages are indicated for two characters, early or late-bolting tendency (4 and 5) and curly top resistance versus curly top susceptibility (7). The pleiotropic effect of gene *m* on other characters was observed only for the type of inflorescence (4), and in a slighter degree for the size of germs (6). Increase in weight of germs in monogerm beets may influence tonnage and sucrose percent, but since sugar content and yield are controlled by special genes, a great pleiotropic action of gene *m* on these characters cannot be expected (3).

The large diversity in sugar content and yield in monogerm lines and hybrids obtained from crosses of monogerm beets to diverse multigerm races can all be regarded as an indirect indication that genes *M* and *m* themselves do not cause big alterations in the characters mentioned. The genetical diversity in monogerm lines is so large that when these lines were used for pollination of male-sterile beets the distinction in sucrose and yield in F_1 hybrids was not less than between varieties of E and Z types.

In our experiment, for example, the hybrid with the monogerm line SLC 602 which showed the highest yield exceeded in yield of gross sugar the commercial variety U. S. 22/3. The hybrid with the monogerm line,

Table 2.—Combining Ability of Four Monogerm Inbred Lines.

	Number of replications	Sucrose	Amino[1] Na	Amino[1] N	Amino[1] K	Beets per plot	Average wt. of roots	Beets per acre	Sugar per acre
		Percent	p.p.m.	Percent	p.p.m.	No.	Pounds	Tons	Pounds
				(Two ZZ lines)					
Male sterile x SLC 600 *mm*	6	16.26	509	0.28	3,213	59.5	2.08	18.3	2,975
Male sterile x SLC 175 *mm*	6	15.37	661	0.37	3,475	56.2	2.17	18.0	2,767
				(Two E-type lines)					
Male sterile x SLC 602 *mm*	3	14.53	764	0.26	3,462	81.7	2.40	29.0	4,214
Male sterile x SLC 609 *mm*	6	13.10	1,018	0.21	3,844	76.6	2.47	27.9	3,655
				Commercial multigerm variety					
U. S. 22/3 (SL 96)	3	13.97	663	0.32	3,444	84.0	2.32	28.8	4,023

[1] Amino nitrogen was determined by the Stanek-Pavlas method using the spectrophotometer as an absorption instrument. The "amino N percent" values reported are based on the concentration of glutamine necessary to produce the same color. True "amino N percent" would be 0.097 times the values given.

SLC 175, which had the highest sucrose percent, hardly reached 75 percent of the yield of gross sugar of U. S. 22/3 (Table 2). The combining ability of four monogerm lines which was established in the given experiment concurred with characteristics of these lines obtained by F. V. Owen, G. K. Ryser, A. M. Murphy and C. H. Smith in F_1 hybrids between these lines and male-sterile multigerm beets (unpublished data). In their experiments the monogerm lines SLC 609 and SLC 602 produced hybrids higher in tonnage, while the hybrids obtained from monogerm lines SLC 175 and SLC 600 showed lower yield but higher sucrose.

Probably the main reason for the difference in sucrose percentage between mono- and multigerm plants of the same hybrid is the linkage of genes. Therefore, in those hybrids where gene *m* is linked with a gene causing low sucrose percent, the monogerm segregates may not be higher in sugar than the multigerm, but in the hybrids in which gene *m* is linked with a gene causing high sugar percentage, the monogerm segregates may exceed the multigerm segregates in sugar content.

In hybrid N 41-42, derived from a heterozygous *Mm* plant crossed to low-sugar line SLC 609 *mm* and in two other hybrids in which the gene *M* originated from high-sugar varieties (Klein Z and U. S. 35/2), the multigerm segregates were higher in sugar than the monogerm. When the same male-sterile lines were crossed to the high-sugar line SLC 600 *mm*, the sugar content in F_1 hybrids was increased (Table 2).

In four hybrids derived from crosses in which the monogerm parent was higher in sugar, the multigerm segregates were a half percent lower (but not statistically significant) in sugar than the monogerm (Table 3).

Table 3.—Sucrose Percentage in Mono- and Multigerm Hybrids and the Origin of Gene *m* in These Hybrids.

MS Hybrid Number	Varieties and inbreds from which the gene *m* originated	Number replicated plots	Sucrose percentage			
			Monogerm hybrids	Multigerm hybrids	Difference	
					Observed	For 5% point of Sig.
	Pollinators (low-sugar monogerm inbreds)					
4142	SL 609 *mm* (gene *m* derived from SL 92)	3	13.00	13.20		
4748	SLC 521 *mm* (SL 92 x SLC 101 *mm*)	3	14.97	15.50		
6463	do.	3	14.97	16.10		
	Total	9	14.31	14.93	.62	.83
	Pollinators (high-sugar monogerm inbreds)					
5354	SLC 175 *mm*	3	15.40	15.33		
4546	SLC 101 *mm*	3	15.17	14.37		
5051	SLC 512 *mm* (U. S. 35/2 x SLC 101 *mm*)	3	15.83	15.37		
5057	do.	3	15.83	15.20		
	Total	12	15.56	15.06	.50	.83
Difference between low-sugar group and high-sugar group			1.25	0.13		
Difference for 5% point of significance			1.10	1.20		

Comparing monogerm hybrids from the two groups (Table 3), the sucrose percentage from the high group is 15.56 as compared with 14.31 from the low group. This difference (1.25 percent) exceeds the calculated difference (1.10 percent) required for t hefive percent point of statistical significance.

Sugar percentage in beets is caused by several genes belonging to different allelomorphs (3). Therefore, complete linkage between theallele *M-m* and high sugar content cannot be expected. This is obvious from the study of segregation in F_2 hybrids between SLC 101 *mm* and multigerm fodder beets (Table 4). Differences in dry matter between mono- and multigerm segregates barely reached an average of 1.5 percent, while the difference between the parental plants was about 8 percent in dry matter.

Table 4.—Results with F_2 Hybrids Between Multigerm Fodder Beet and Monogerm SLC 101 *mm*.

Type of fruit	Number of plants with the following percent of dry matter: 12	13	14	15	16	17	18	19	20	21	Total plants	Dry matter
												Percent
Monogerm			2	1	2	8	4	3	1	1	22	17.31 ± .37
Multigerm	2	5	7	15	13	7	7	3	4		61	16.00 ± .25

Summary

Beets grown from single-germ and multigerm fruits having the same genotypes with respect to genes *M* and *m*, taken from heterozygous *Mm* plants, did not show evident differences in sucrose percentage.

New monogerm lines obtained from hybridization of the original monogerm line SLC 101 *mm* to multigerm curly-top-resistant varieties are often good in sugar. This advantage in sugar content observed in monogerm beets may have been caused by the linkage of a *M-m* allelomorph with one allele, determining the percentage of sucrose in beets, but not by a general pleiotropic action of the gene *m* itself.

Many recessive homozygous genes in beets, as in other plants, have a negative selective effect (1 and 3). Similar genes are, for example, the genes pl (plantaginifolia), bl (black root), re (reduction of leaf blades), genes causing chlorophyll deficiency, etc. Fortunately, the gene *m* does not belong in a class with such genes. The gene *m* itself cannot cause a wide variation in sugar content or in yielding capacity. These characters are controlled by special genes which are responsible for the differences in sucrose and yield between E and Z types sugar beets, fodder beets and other beet varieties.

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Self-Sterility and Self-Fertility in Monogerm Beets

HELEN SAVITSKY[1]

Introduction

Development of self-sterile monogerm races of beets is important for the production of self-sterile monogerm commercial sugar beet varieties. The first experiments conducted for this purpose were described in 1952 (2)[2]. Further work was directed to: 1. selection and development of self-sterile monogerm beets, and 2. a study of a type of self-fertility, the inheritance of which did not correspond to the personate type of self-fertility.

Material and Methods

To obtain self-sterile monogerm beets, F_1 hybrids between the original self-fertile monogerm line SLC 101 and self-sterile multigerm varieties were crossed back to multigerm beets. F_1 hybrids used in this experiment were derived from crosses of SLC 101 to different curly-top-resistant strains, to nonbolting strains and to European Z- and E-type varieties. The first F_1 hybrids originated from the natural hybridization of the original monogerm plant SLC 101 *mm* under open pollination to Michigan Hybrid 18 in Oregon. These were also used.

Selection for self-sterility was conducted in b_1 generations and for the monogerm character in self-sterile beets in the b_2 generations (8). The first self-sterile monogerm plants were selected in the summer of 1952 in b_2 progenies of F_1 hybrids derived from natural hybridization of SLC 101 *mm* and backcrosses to curly-top-resistant strains. In 1952 new self-sterile monogerm beets were selected from other hybrid combinations. The selected self-sterile monogerm plants were intercrossed by exchanging pollinating bags.

The progenies derived from crosses of two self-sterile monogerm plants were checked for self-sterility the following year. For this purpose, in each F_1 progeny 15 to 20 plants were bagged and examined for self-sterility versus self-fertility during the flowering period. A total of 39 F_1 progenies was examined in 1952, and 25 in 1953. Self-sterile plants selected in these progenies were propagated in isolated groups under open pollination after the paper bags were removed. These self-sterile monogerm plants represented the initial material for development of self-sterile monogerm populations. Some progenies which segregated for self-sterile and self-fertile plants were taken for a study of the inheritance of self-fertility. The grade of self-fertility was established by determination of the percentage of selfed seed under the paper bags.

Because all these plants were monogerm, the percentage of selfed seed could be established exactly. The segregation in only part of the lines studied will be presented in this paper.

Experimental Results

According to the oppositional factor hypothesis, all F_1 plants obtained from crosses between two self-sterile monogerm plants are expected to be

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[1] Collaborator Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture in cooperation with the Beet Sugar Development Foundation.

[2] Numbers in parentheses refer to literature cited.

self-sterile. However, different F_1 plants were very different in their degree of self-sterility. Complete self-sterility was observed in F_1 progenies which arose from crosses of SLC 101 *mm* to different self-sterile strains and varieties (curly-top-resistant varieties from U. S. 22/3 and U. S. 75, and curly-top-susceptible varieties Janash, Klein E and Klein Z) and backcrosses to the same varieties.

About 400 plants, checked for self-sterility in 25 lines, proved to be highly self-sterile. Some self-fertile plants were observed only in one line, but F_1 lines derived from hybridization of SLC 101 *mm* to "Michigan Hybrid 18" under open pollination and backcrossed to curly-top-resistant strains showed a different picture. Only five F_1 lines out of 39 were completely self-sterile and this characteristic was repeated during two seasons. The other 34 F_1 lines consisted of both self-sterile and self-fertile plants.

The percentage of self-fertile plants varied in different lines from 5 to 87. Four lines, N 31-5, N 31-3, N 12-5 and N 32-6, which contained 87, 74, 25 and 18 percent self-fertile plants respectively, were chosen for further study. The line 32-6 showed not only a small percentage of self-fertile plants, but also the degree of self-fertility in the self-fertile plants was low. The amount of selfed seed in the self-fertile plants of this line did not exceed three percent. Three other lines contained plants which showed a low or intermediate degree of self-fertility and also plants which set about 60-70 percent of selfed seed.

Selfed seed from different plants within these partially self-fertile lines was planted and the beets grown from it were examined under paper bags for self-sterility versus self-fertility. The self-sterile F_1 plants from the low self-fertile line 32-6, when crossed to each other, produced completely self-sterile F_2 progeny.

The progeny obtained from selfed seed of plants with a low degree of self-fertility from this line (with one and three percent of seed set) consisted of 30 plants, 24 of which were entirely self-sterile, and six showed a low degree of self-fertility (the percentage of selfed seed varied in different plants from 0.5 to 5). It might be that such a low percentage of selfed seed could be caused by environment and those beets with a low degree of self-fertility might have been self-sterile. But the probability of the existence of special genes causing low degrees of self-fertility is not excluded and must be proved by further study. It is interesting to note that many American and European self-sterile sugar and fodder beet varieties contained one to five plants per 100 plants bagged which set about 5 to 15 fruits per plant.

The F_2 segregates from three other lines, N 31-3, 31-5 and 12-5 showed continuous variation from completely self-sterile plants through different intermediate grades of self-fertility to highly self-fertile plants. The majority of segregates was self-fertile, but all lines segregated at the same time for self-sterile plants. The F_2 segregates obtained in thees three lines and the degree of self-fertility are shown in Table 1.

All self-sterile monogerm plants, selected for self-sterility at the time of flowering of F_1 progenies from crosses of two self-sterile monogerm beets,

Table 1.—Segregation for Self-Fertility Versus Self-Sterility in Three Partially Self-Fertile F_2 Progenies from Selfed F_1 Plants.

	Degree of self-fertilization, percent selfing as follows:																						Total
	0	1	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95		plants
Number of plants per class	21	2	3	3	2	2	4	5	5	11	6	5	7	3	2	4	2	2	..	1	2		92

were placed together in an isolated group for production of seed under open pollination. Only the lines which segregated for a high percentage of self-fertile plants were excluded. This type of selection for self-sterile F_1 plants was conducted during two years with material of different origin. Seed obtained from self-sterile monogerm plants was planted in the fall of 1952 and the first self-sterile monogerm population was grown from it in 1953. During flowering time several plants (about 100) in this population were bagged to check for self-sterility versus self-fertility. No self-fertile plants were found among them.

Seed harvested from this population was furnished to the Beet Sugar Development Foundation. Sam Campbell, manager of the West Coast Beet Seed Company, planted one acre in Oregon for seed production in 1954. During 1952 and 1953 pollen of self-sterile monogerm plants was used for hybridization with different self-sterile multigerm varieties for the development of self-sterile monogerm strains with different utilitarian characters and of different origin.

Discussion

A high degree of self-fertility in sugar beets is caused, as indicated by F. V. Owen (6), by the factor S^f which is a member of the *S* allelic series. The inheritance of this type of self-fertility versus self-sterility is explained by the oppositional factor hypothesis. According to this hypothesis the pollen tubes which carry the S^f factor can grow through pitstils with S^f or any other factor of the *S* series. Pollen tubes with an *S* factor are not effective on the pistils with the same identical *S* factor. The same type of inheritance of self-sterility and self-fertility has been described in many other crop plants (1, 2, 3, 5, etc.).

The personate type of inheritance of self-fertility leads to the following important consequences: 1. Hybrids between self-sterile and self-fertile plants in F_1, F_2 and all succeeding selfed generations are highly self-fertile and constant in this character. 2. Self-fertile plants cannot produce a self-sterile offspring, unless some gamete carrying an *S* factor may occasionally fertilize an egg cell also bearing the same *S* factor. 3. Self-fertile plants cannot appear in the progeny of self-sterile plants, unless a new mutation for the S^f factor occurs. 4. The segregation for self-sterility versus self-fertility in a 1:1 ratio takes place only in the b_1 generation after the backcross of F_1 hybrids to self-sterile plants. These b_1 segregates can be highly self-fertile or completely self-sterile; no plants with intermediate degree of self-fertility should appear.

When SLC 101 *mm* was crossed to different self-sterile multigerm varieties, the inheritance of self-steriltiy versus self-fertility in hybrids followed the above described personate type of inheritance. F_1, F_2 and all

following selfed generations were highly self-fertile. Thousands of different hybrids derived from SLC 101 *mm* were observed during the last few years. They all showed this high degree of self-fertility. Thus, the inbred line SLC 101 *mm* carried in its genotype the S^f factor for self-fertility. After backcrosses to self-sterile multigerm beets, the segregation for self-sterility versus self-fertility was observed in b_1 generations.

The majority of lines segregated in the b_1 generation for only highly self-sterile and highly self-fertile plants in a 1:1 ratio (8). In some lines a few semi-self-fertile segregates appeared. Their appearance was caused, not by the action of the gene S^f, but by some other factors.

The self-sterile plants selected in b_1 and self-sterile monogerm plants selected in b_2 were free from the S^f factor. The corresponding allelomorph in these plants carried only the gene *S* for self-sterility, but when such self-sterile plants (whose ancestors originated from the strain "Michigan Hybrid 18") were crossed together, new self-fertile plants appeared in their progeny. The appearance and behavior of such plants could not be explained on the basis of the personate type of inheritance.

Characteristics of these new self-fertile plants were: 1. Self-fertile plants appeared in the progeny of self-sterile parents. 2. The progeny of selfed self-fertile plants consisted of plants with different degrees of self-fertility from low to highly self-fertile. 3. Progenies from self-fertile plants always segregated for a small number of self-sterile plants.

This type of inheritance of self-fertility which was observed in self-fertile plants was close to the associate type of self-fertility described in some other crops (4, 7, 9). Both parental plants of the lines in which this type of self-fertility was observed originated from the strain "Michigan Hybrid 18." The strain "Michigan Hybrid 18" is predominantly self-sterile, but genes for self-fertility were dispersed in this population. About 90 percent of the plants of this strain were self-sterile but plants with intermediate degrees of self-fertility and highly self-fertile plants were found. The selected beets in this strain, SLC 101 *mm*, SLC 100, SLC 27, SLC 99, SLC 107 *mm* were highly self-fertile. Genetic studies of this type of self-fertility will be continued.

A study of the inheritance of the associate type of self-fertility in beets is very important because low and intermediate degrees of self-fertility are more common in beet populations. Highly self-fertile plants caused by the presence of the S^f gene, the behavior of which is based on the personate type of inheritance, are rare in populations. Such races were found by Dr. F. V. Owen and Dr. V. F. Savitsky in America and by T. Grinko in Russia. Many investigators in different countries worked with self-fertile races of the associate type. For this reason they often could not obtain highly self-fertile constant lines in spite of selection in populations for highly self-fertile plants. The knowledge of the inheritance of an intermediate type of self-fertility is important for us also for the development of highly self-sterile populations.

Summary

For development of self-sterile monogerm beets F_1 hybrids between SLC 101 *mm* and self-sterile multigerm strains and varieties were crossed

back to self-sterile plants. The first self-sterile monogerm population was produced from self-sterile monogerm beets selected in the b_2 generation.

Some F_1 lines derived from crosses between two self-sterile monogerm plants segregated for self-sterile and self-fertile plants differing in degree of self-fertility. A study of plants with intermediate degrees of self-fertility showed that they followed the associate type of inheritance.

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Study of Inheritance for Curly Top Resistance in Hybrids Between Mono- and Multigerm Beets

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Introduction

Sugar beet plantings in Europe and in certain areas of America are free from the curly top disease. But in some areas, such as portions of Utah, Idaho, California, etc., the damage caused by curly top is often so severe that beet growing would not be possible with European or American curly-top-susceptible varieties.

Thanks to work conducted by previous investigators (2, 3, 4, 5, 6, 7 and 9)[2], varieties resistant to curly top have been developed during the last two decades. The first resistant variety U. S. 1, was composed of several non-related populations originating from different varieties characterized by a large genetical diversity selected for curly top resistance. This peculiarity predetermined the probability of further continuous improvement of variety U. S. 1. New varieties developed from the variety U. S. 1 surpassed the original variety in resistance to curly top.

Thanks to different directions of selection for utilitarian characters which were applied, the new curly-top-resistant varieties belonging to yield and sugar types were developed. The sugar industry in areas affected by curly top is now completely based on acclimated curly-top-resistant varieties. The replacement of multigerm curly-top-resistant varieties with monogerm varieties has made it necessary to hybridize the curly-top-susceptible SLC 101 monogerm line with the best available curly-top-resistant varieties possessing different utilitarian characters. Genetic and breeding investigations reported in this paper are based on hybrids obtained for this purpose.

Methods

The sugar beet varieties involved in the program to study curly top resistance in hybrids between multi- and monogerm beets were reported in a preceding paper (8). The description of the first two hybrid generations was also given in the above mentioned paper. In this report, which represents the continuation of the preceding paper, we give mainly the results of the study in F_3 and F_4 hybrid lines.

The F_3-F_4 hybrids, derived from the monogerm line SLC 101 crossed to different curly-top-resistant varieties, were planted during the past three years at Jerome, Idaho, and at Salt Lake City, Utah. The usual genetic method of analyzing F_2 and backcross populations was modified a little when the inheritance for curly top resistance was studied. It was impossible to obtain F_3 lines from curly-top-susceptible plants. Therefore, the F_2 plants were grown under conditoins free from curly top and selfed without choice.

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[1] Collaborator and Agronomist, respectively, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture, in cooperation with the Beet Sugar Development Foundation.

[2] Numbers in parentheses refer to literature cited.

Experimental Results

Resistance to Curly Top in Monogerm Lines Under a Mild Curly-Top Exposure

The injury caused by curly top was so slight on the experimental field at Salt Lake City in 1952 that only a trace of the disease was shown on a small percentage of plants of the curly-top-resistant variety U. S. 22/3 (Table 1). For U. S. 22/3 the average curly top grade was 1.25 (on a basis of 1 to 5 in order of degree of disease injury). Inbred line SLC 101 *mm* showed comparatively heavy injury under these conditions (the curly top grade was 3.25), and the majority of plants in this line were useless for seed production.

The monogerm inbred lines derived from crosses between the curly-top-resistant multigerm strain SL 92 (a curly-top-resistant selection from U. S. 22/3) and SLC 101 *mm* showed different degrees of curly top resistance (Table 1). In spite of their variability they made a good impression because the majority of them were characterized by a good average resistance and lines damaged more heavily than SLC 101 *mm* were absent among them. From 61 monogerm inbred lines examined, only five showed the same degree of injury as the parental line SLC 101 *mm*. Thirteen of the 61 monogerm lines received the same curly-top grade as the resistant multigerm variety U. S. 22/3. Thus, in this experiment is was observed that the segregation of monogerm lines for curly top resistance included lines with resistance corresponding to that of parental strains.

The monogerm inbred lines derived from curly-top-susceptible multigerm varieties crossed to SLC 101 *mm* (Table 1) were studied in the same

Table 1.—Curly Top Grades for F_3 Monogerm Lines Under a Mild Curly Top Exposure at Salt Lake City in 1952.

Origin	Number of lines with curly-top grades[1] as follows:															
	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.60
Parental lines or varieties																
U. S. 22/3 (SL 96)		1	1													
SLC 101 *mm*										1	1					
Kleinwanzleben											1					
F_3 monogerm lines																
SL 92 x SLC 101 *mm*	3	5	5	9	14	14	3	3		3	2					
SL 824 x SLC 101 *mm*		1	1	1		1		1		1						
Lanker x SLC 101 *mm*						1		4	2	2						
Kleinwanzleben x SLC 101 *mm*					1	2	1	1	4	3	3	4	1		1	
U. S. 216 x SLC 101 *mm*									1	4	3	1	1			
Mich. 18 x SLC 101 *mm*									1	2	2	3	3			
Red Egyptian x SLC 101 *mm*										1	1	3	1	2		1

[1] Curly top grades established as follows:
1 plants showing very few symptoms or were not injured
2 plants showing slight leaf curling
3 plants showing pronounced curling and some dwarfing. (Fruitless)
4 plants showing pronounced curling and dwarfing. (Fruitless)
5 plants showing near death from the disease. (Fruitless)

experiment. The majority of these lines showed heavy injury caused by curly top. However, some of these monogerm lines showed some curly top resistance, in spite of the fact that none of the parental multigerm varieties was selected for curly top resistance.

The most susceptible monogerm lines were derived from crosses between SLC 101 *mm* and Egyptian red table beets. About three-fourths of the lines originating from this hybrid combination showed much heavier injury than SLC 101 *mm*. The monogerm lines obtained from crosses of SLC 101 *mm* with multigerm beets from Michigan hybrid 18 or from crosses with the leaf-spot-resistant variety U. S. 216 were also susceptible. Half of these lines were injured more severely than SLC 101 *mm*. The monogerm lines obtained from hybridization of SLC 101 *mm* with the curly-top-susceptible multigerm variety Kleinwanzleben showed a large diversity in degree of resistance. Highly resistant lines were not observed among this material, but lines lower in resistance than SLC 101 *mm* were observed frequently.

Hybridization of SLC 101 *mm* with certain fodder beet varieties (for example, with Lanker) gave better results. The curly top resistance in monogerm lines derived from these crosses was better than in SLC 101 *mm*. But the lines with really high resistance were absent in this material, too.

Study of Monogerm Lines Under a Severe Curly Top Exposure

Curly top infection was more severe on the experimental plot at Jerome, Idaho, than at Salt Lake City, Utah, in 1952. The severe damage of beets at Jerome, Idaho, was caused by an artificial disease exposure and by a special method of planting (Table 2).

Table 2.—Curly-Top Grades of Sugar Beet Varieties Under a Severe Curly Top Exposure at Jerome, Idaho, in 1952.

Variety	Number of plants with curly top grades as follows: 1	2	3	4	5	Number of plants	Average curly top grade
U. S. 22/3	34	46	28	8		116	2.08
SL 824	12	21	9	8		50	2.26
U. S. 33	16	17	36	55	5	129	3.15
Kleinwanzleben			3	59	46	108	4.39
SLC 101 *mm*				13	4	17	4.23

Under conditions of the severe disease exposure, plants about to perish were observed, not only in the susceptible varieties such as Kleinwanzleben, but also in varieties such as U. S. 33 with intermediate resistance (Table 2). All plants in SLC 101 *mm* were injured so badly that they could not produce seed. The curly-top-resistant variety U. S. 22/3 showed no badly injured plants, although a few plants showed obvious traces of curly top injury. The majority of plants in this variety grew normally throughout the season.

The monogerm lines, derived from hybridizing SLC 101 *mm* with multigerm curly-top-resistant varieties, showed different degrees of curly top resistance under the severe disease exposure. Here the grade of resistance of the parental multigerm varieties was shown, but also in correspondence with the method of selection of F_2 plants from which the inbred lines were obtained. The monogerm lines derived from F_2 plants which were selected

for curly top resistance were distinguished from the lines originating from F_2 plants selected only for vigor and for seed quality. At the same time the lines which were exposed to any kind of selection differed from the lines which were developed for a study of inheritance of curly top resistance and were not selected. The behavior of each group of lines is discussed separately.

The F_3 monogerm lines obtained for the study of inheritance of curly top resistance will be discussed first. Among the F_1 hybrid families derived from crosses of multigerm curly-top-resistant beets with SLC 101 *mm*, two F_1 progenies, selected for increased vigor and resistance, were chosen. One plant in such a progeny was selfed for further work. F_2 seeds were planted in August at Salt Lake City under disease-free conditions. In the winter all plants without any eliminations were transplanted into the greenhouse and self-pollinated under paper bags. Seed was harvested from each plant separately and the F_3 lines were planted in the spring at Jerome, Idaho. In this way F_3 lines were obtained from F_2 plants which were not selected for resistance to curly top or vigor, nor for the mono- or multigerm character.

Forty-two F_3 lines from the first family (No. 521), derived from crosses of the multigerm strain SL 92 with SLC 101 *mm*, were segregated mainly for lines with low and intermediate grades of curly top resistance (Table 3).

Table 3.—Curly Top Resistance in Mono- and Multigerm F_3 Lines Under a Severe Curly Top Exposure at Jerome, Idaho, in 1952.

	Number of lines with curly top grade as follows:										Total lines	Average curly top grade
	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50		
Multigerm and monogerm parents														
U. S. 22/3 multigerm	1		1											
SLC 101 *mm* monogerm														
F_3 lines (SL 824 x SLC 101 *mm*)														
Total of 28 lines			3	1	3	4	4	7	2	3	1		28	3.49
Classified monogerm and multigerm:														
Monogerm (*mm*)						1	2		2	1	1		7	3.61
Multigerm (*MM* + 2 *Mm*)			3	1	2	2	4	5	1	2	1		21	3.45
Classified on hypocotyl color:														
White hypocotyls (*rr*)			2	1	1			3	1	1			9	3.36
Red hypocotyls (*RR* + 2 *Rr*)			1		2	4	4	4	1	2	1		19	3.55
F_3 lines (SL 92 x SLC 101 *mm*)														
Total of 42 lines					2	10	12	11	7				42	3.56
Classified monogerm and mulitgerm:														
Monogerm (*mm*)							1	3	1	4			9	3.72
Multigerm (*MM* + 2 *Mm*)					2	9	9	10	3				33	3.52
Classified on hypocotyl color:														
White hypocotyls (*rr*)					1	4	3	1	2				11	3.47
Red hypocotyle (*RR* + 2 *Rr*)					1	6	9	10	5				31	3.59

In spite of the large number of lines which resembled the susceptible parental line SLC 101 *mm* resistant lines corresponding to the second parent, SL 92, were completely absent. The monogerm F_3 lines in this family appeared very different in curly top resistance (Table 3), and the resistance was on an average lower in monogerm lines than in multigerm lines from the same hybrids.

In the second family, derived from hybridization of SLC 101 *mm* with a multigerm curly-top-resistant clone (isolated from the strain SL 824), the F_3 families showed larger variations in degree of resistance (Table 3). Some lines appeared which were even more susceptible than SLC 101 *mm*. For the best lines the curly top resistance approached that of U. S. 22/3. However, no line fully reached the grade of resistance of U. S. 22/3. The monogerm lines were lower in resistance to curly top than the multigerm lines in these F_3 families.

Because of the linkage established by Abegg and Owen (1), the lines with white hypocotyl color in both families were more resistant than the lines with red hypocotyl color. SLC 101 *mm* is homozygous *RR* for red hypocotyl color. All multigerm beets used for the hybrids with SLC 101 *mm* were selected from the recessive *rr* hypocotyl color. Six monogerm lines derived from the SL 824 multigerm clone crossed to SLC 101 *mm* were studied the same year at Salt Lake City where the curly top exposure was relatively mild. Under this mild curly top exposure two monogerm lines showed very high resistance and were just as free from curly top as the highly resistant strain SL 92. Three other monogerm lines showed an intermediate degree of resistance and only one line showed resistance as low as that in the SLC 101 *mm* (Table 1).

Thus the estimation of the grade of curly top resistance varied according to the intensity of injury. The genotypes which were able to resist the damage under a mild disease exposure were not sufficiently resistant under a severe curly top exposure.

Curly Top Resistance in Monogerm Lines Obtained After Selection for Vigor and Quality of Seed

F_2 hybrids between multigerm curly-top-resistant beets and SLC 101 *mm* were selected for vigor and for quality of monogerm fruits in 1951. They had not been selected for curly top resistance. The monogerm lines, derived from F_2 plants selected for vigor, showed higher resistance to curly top at Jerome, Idaho, in 1952 than the lines whose F_2 ancestors were not selected for vigor (Table 4).

Sixty-two monogerm F_3 lines were obtained from selfing and seventy-two F_3 monogerm lines were obtained under open pollination. Among selfed, and especially among open-pollinated lines obtained after selection for vigor, there appeared new lines in which the curly top resistance equaled that in the variety U. S. 22/3. Lines with this high degree of curly top resistance were absent among material not selected for vigor.

F_3 Monogerm Lines Derived from F_2 Plants Selected Once for Curly Top Resistance

The monogerm lines derived from F_2 plants selected for curly top resistance at Jerome, Idaho, in 1952 showed the highest degree of curly top

resistance. The grade for curly top resistance on the experimental plot at Jerome, Idaho, in 1950 was very close to that in 1952. Under these conditions all curly-top-susceptible plants (for example, in the variety Kleinwanzleben or in the line SLC 101 *mm*) were damaged so heavily that they could not produce seed. The F_2 hybrids derived from crosses of curly-top-resistant multigerm varieties with SLC 101 *mm* were also severely injured. Every F_2 hybrid was planted in one row 480 feet long. Although about 50 F_2 hybrid families were planted, we obtained seed from only about 30 monogerm plants.

Table 4.—Curly Top Grades for Monogerm Lines Derived from Crosses of SLC 101 *mm* to Curly-Top-Resistant Multigerm Beets Under a Severe Curly Top Exposure at Jerome, Idaho, in 1952.

Origin	Number of lines with curly top grades as follows: 1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	No. of lines	Average C.T. grade
U. S. 22/3			1	1	1											
U. S. 33							1		1							
SLC 101 *mm*												1	1			
Kleinwanzleben													1			
Selfed lines, without selection						3	1	5	14	16	18	9	3	1	70	3.54
Selfed lines, selected for vigor				3	5	9	10	7	7	6	5	10			62	3.08
Open-pollinated lines selected for vigor				2	12	13	13	12	5	6	5	3	1		72	2.88
Lines from F_2 plants selected for curly top resistance	1	2	3	7	1	8	3	3	1						29	2.28

The small number of monogerm F_2 plants which were able to produce seed can be explained not only by the heavy injury caused by curly top, but also by the fact that the percentage of monogerm plants which showed a high degree of resistance to curly top among the F_2 populations was very low.

The same F_2 hybrids segregated for the usual percent of monogerm plants (25 percent) of F_2 populations were not exposed to curly top. Curly top eliminated a higher percentage of monogerm than multigerm plants.

Table 4 illustrates 29 more highly resistant F_3 monogerm lines whose parents (F_2 plants) were selected for curly top resistance. Fifty percent of these lines showed resistance very close to that of the original curly-top-resistant variety U. S. 22/3. Thus, the selection for curly top resistance proved to be highly effective.

Resistance for Curly Top in Monogerm Lines Under an Extremely Severe Curly Top Exposure

The curly top injury to monogerm lines at Jerome, Idaho, was much stronger in 1953 than in 1952. In all curly-top-susceptible strains (SL 101 *mm*, Kleinwanzleben, etc.) 100 percent of the plants died by late August. Even in the resistant variety U. S. 33 only 18 percent of the plants survived. The plants which did survive were so badly injured by curly top that most

were not capable of producing seed. The curly-top-resistant strain SL 92 was also badly damaged and only 33 percent of the plants survived. The majority of these plants were also useless for seed production (Table 5). It was natural that monogerm lines derived from crosses of SLC 101 *mm* with SL 92 and SL 824 were injured very heavily and in the hybrid lines obtained from curly-top-susceptible varieties crossed to SLC 101 *mm* almost all plants failed to survive.

Complete loss of plants was also observed in those selfed monogerm lines which were obtained from hybridization of multigerm curly-top-resistant varieties with SLC 101 *mm* and derived from F_2 lines which were not selected for curly top resistance, vigor or quality of seeds. Forty-four such lines were lost entirely. Thirteen monogerm lines of the same origin, also not selected but propagated under open pollination, maintained one plant in four or five lines.

In sixty-two selfed monogerm lines, derived by selfing F_2 monogerm plants exposed to selection for vigor, 16 lines were maintained.

Eighty-eight monogerm lines, also selected for vigor in F_2 populations, but propagated under open pollination, showed much higher resistance to curly top. Among them 48 percent of the lines remained.

Table 5.—Number of Lines with One or More Surviving Plants Under an Extremely Severe Curly Top Exposure at Jerome, Idaho, in 1953.

	Method of propagation	With no surviving plants	With the following number of surviving plants: 1	7	13	19	25	31	37	43	49	55	Number of lines	Percent of surviving lines	Average curly top grade of surviving plants
U. S. 22/3	Op. poll.					1	1		3				5[1]		
U. S. 33	Op. poll.		2	6	8	9	2	3					30[1]		
SLC 101 *mm*	Selfed	1											1		
	Monogerm lines selected for curly top resistance														
	Op. poll.	1	2	4	5	5	1	1	1				20	95.0	4.64
	Selfed	17	2		7	4	1					1	32	46.8	4.88
	Monogerm lines selected for vigor														
	Op. poll.	46	11	12	2	13	1	2		1			88	47.72	4.81
	Selfed	52	3	3	2	2							62	16.12	4.92
	Monogerm lines with no selection														
	Op. poll.	11	2										13	15.3	5.00
	Selfed	44											44	0.00	.....

[1] Multigerm varieties used for comparison were repeated several times. There were 5 repetitions of U. S. 22/3, 30 of U. S. 33 and 3 of 4*n* curly-top-resistant selections.

The best of these monogerm lines maintained almost the same number of plants as multigerm curly-top-resistant varieties (Table 5). The curly top grade for the best lines was very close to that for variety U. S. 22/3.

The high effectiveness of selection for curly top resistance which was observed in the 1952 experiments became still more pronounced under conditions of the extremely high curly top exposure in 1953. The curly top resistance was the highest in those monogerm lines which originated from F_2 plants selected for curly top resistance at Jerome, Idaho, in the previous generation (Table 5). From thirty-two selfed lines exposed to the additional selection for curly top resistance 47 percent of the lines survived. From twenty monogerm lines which were also exposed to selec-

tion for curly top resistance, but propagated under open pollination, 95 percent of the lines survived. The average curly top grade for surviving plants in these lines was on the average lower than for the multigerm variety U. S. 22/3, but some individual lines showed a higher degree of resistance to curly top equivalent to that in the strain SL 92.

Curly-top Resistance in F_2 Hybrids Between Curly Top resistant Varieties and Monogerm Lines Selected for Curly Top Resistance

F_2 hybrids between the multigerm curly-top-resistant strain SL 92 and SLC 101 *mm* showed low resistance to curly top under a servere curly top exposure. Such F_2 hybrids, derived from selfed F_1 plants, practically perished in the Jerome, Idaho, plantings in 1953 (Table 6).

Table 6.—Segregation for Curly Top Resistance in F_2 Hybrids and in the Most Resistant Monogerm Lines at Jerome, Idaho, in 1953.

	Method of propagation	Number of plants with curly top grades as follows: 1	2	3	4	5	No. of surviving plants	Average curly top grade
U. S. 22/3	Open poll.			3	18	20	41	4.41
SLC 101 *mm*	Selfed						0[1]	
SLC 600 *mm*	do.				1	1	2	4.50
SLC 175 *mm*	do.					6	6	5.00
4*n* SL 92	Open poll.		10	8	18	8	44	3.54
	F_2 populations							
(SL 92 x 101 *mm*)	Se'fed						0[1]	
(SL 92 x SLC 600 *mm*)	do.					3	3[1]	5.00
(SL 824 x SLC 175 *mm*)	do.					6	6	5.00
(SL 92 x SLC 175 *mm*)	Open poll.		2	20	18	10	50	3.72
(SL 824 x SLC 175 *mm*)	do.		8	18	9	20	55	3.74
	The best curly-top-resistant monogerm lines							
	Selfed				8	16	24	4.67
	do.				6	18	24	4.75
	do.			2	6	20	28	4.64
	do.				4	56	60	4.93
	do.				2	22	24	4.91
	Open poll.			1	6	18	25	4.68
	do.			5	6	20	31	4.48
	do.			7	10	22	39	4.38
	do.			5	8	7	20	4.10
	do.			1	8	9	18	4.44

[1] All plants killed by curly top.

F_2 hybrids between the same multigerm beets and the more resistant monogerm lines SLC 600 *mm* or SLC 175 *mm* were more resistant (Table 6) Inbred lines SLC 175 *mm* and SLC 521 *mm* were derived from F_2 plants selected for curly top resistance. Therefore, their hybrids with curly-top-resistant beets essentially represented backcross hybrids.

Segregation for curly top resistance in the best F_2 populations obtained from crosses between SL 92 and SLC 101 *mm* and from SL 92 crossed to SLC 600 *mm* and SLC 175 *mm* varied, depending upon the method of propagation of F_1 plants. Even one selfing decreased the resistance of hybrids and caused a thin stand.

The F_2 populations, derived from crosses to SLC 600 *mm* or SLC 175 *mm* and open pollination of F_1 plants, contained many more resistant beets than the best curly-top-resistant monogerm lines obtained from crosses with SLC 101 *mm* (Table 6).

Selection of curly top resistant plants in F_2 hybrids between SL 92 and SLC 175 *mm* or SLC 600 *mm* was conducted at Twin Falls in 1952. The performance of selections showed that these hybrids produced many curly top resistant monogerm plants because of the breaking of the previous linkage between the *Mm* allelomorph and one of the genes for curly top resistance.

Conclusions

Under a mild curly top exposure the majority of monogerm inbred lines derived from crosses of multigerm curly-top-resistant varieties with the original monogerm line SLC 101 *mm* showed good or medium resistance. The lines which were damaged more than SLC 101 *mm* were absent. There were two or three times as many curly-top-resistant lines as there were susceptible lines. In the group of lines which showed an intermediate degree of resistance between that of the parental lines, higher resistance prevailed. Thus, under a mild disease exposure, resistance to curly top seems to be a dominant character. This was also confirmed by a study of corresponding F_1 and F_2 hybrids.

The excessive number of resistant plants over the number of heavily injured led the first investigators who studied inheritance for curly top resistance in beets (1) to assume a dominant gene for a relatively high degree of curly top resistance. When the hybrids between different curly-top-susceptible varieties were studied, many facts indicated that the resistance to curly top is of a more complicated genetical nature, even under mild exposures.

After hybridization of the curly top susceptible monogerm line SLC 101 *mm* with different susceptible multigerm varieties, the type of F_2 segregations and the behavior of corresponding F_3 lines were different in different hybrids. These differences were observed although the parental European varieties of sugar and fodder beets were not selected for curly top resistance. Hybridization of SLC 101 *mm* with some curly-top-susceptible varieties produced monogerm lines still more susceptible than SLC 101 *mm*.

Hybridization of SLC 101 *mm* with other curly-top-susceptible varieties gave some lines with higher resistance than the original monogerm parent. However, among all hybrids between SLC 101 *mm* and curly top susceptible varieties, lines with high curly top resistance were not observed. These experiments led to the conclusion that although the populations of many curly top susceptible varieties contain genes which cause partial resistance, the development of highly resistant beets requires synthesis of such genes in one genotype. The curly-top-susceptible line SLC 101 *mm* carries some genes which enable it to resist curly top injury more than some other susceptible varieties.

The above type of segregation was not observed when the curly top exposure became stronger. The changes in segregation were so large that

the percentage of segregating plants was changed, and, also, the parental type did not appear. The dominance of the character for resistance to curly top also changed.

The presence of many plants in hybrid populations which showed resistance to curly top under a mild curly top exposure gave an impression of dominance for this character. This impression of dominance disappeared under a severe curly top exposure.

This type of segregation, in which the resistance to curly top was not dominant, was observed in 70 selfed F_3 lines under a severe disease exposure. These lines were developed from two hybrids derived from crossing SLC 101 *mm* with two curly-top-resistant varieties. One family, which consisted of 42 lines, did not contain any line with a grade of resistance equal to that of the curly top resistant parent. At the same time 7 lines from this family showed susceptibility equal to that of SLC 101 *mm*. In a monohybrid segregation ten curly top resistant and ten curly top susceptible lines could be expected; in a di-hybrid segregation both parental classes should contain two or three lines. But we did not observe in this family of lines any line which belonged to the class of the resistant parent.

Thus, the resistance to curly top in this family of lines was caused by more than two pairs of genes. The genetical complexity of this character was also confirmed by another family which consisted of 28 F_3 lines. The plants resistant to curly top in the same degree as the resistant parent were absent in this hybrid, too, although there were plenty of susceptible plants. The segregation in this family of lines was still more complicated because the amplitude of variation for curly top resistance was large and even plants more susceptible than SLC 101 *mm* appeared in the segregating populations. The resistance to curly top in such families depends upon more than two pairs of genes.

Both hybrid families segregated for resistance to curly top and for the mono- and multigerm character simultaneously. F_3 lines represented progenies from different F_2 segregates. The monogerm F_3 lines in both families showed lower resistance than the multigerm lines. The same situation was also observed in F_2 populations. Therefore, among F_2 plants selected for curly top resistance an obvious deficiency of monogerm plants was noticed. But the same hybrids segregated for a normal percentage (25 percent) of monogerm plants under conditions where the plants were not eliminated by curly top. Therefore, one of the alleles which controls resistance to curly top is in the same linkage group with the *Mm* allele.

Segregation observed in these hybrids for hypocotyl color confirmed results obtained by Abegg and Owen (1) that linkage exists between the *Rr* allele and resistance to curly top.

The resistance to curly top in F_3 lines was improved if the F_2 ancestors were selected for vigor and quality of fruits. Greater improvement was observed in those monogerm F_3 lines which were derived from F_2 plants selected for curly top resistance under a severe disease exposure where low resistant plants were eliminated. On the average, the monogerm lines obtained from selfing showed lower resistance than the corresponding

lines after open pollination among the same breeding group. Genes responsible for a decrease in vigor during the process of inbreeding also decrease the effectiveness of genes responsible for resistance to curly top.

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Preliminary Yield Tests with F_1 Male-Sterile Monogerm Hybrid Sugar Beets

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Introduction

One advantage of the monogerm character in beets is the clear-cut single-gene type of inheritance (4[2]). Another advantage, at least for the immediate future, is the behavior of this character in F_1 male-sterile hybrids. The monogerm, or multigerm, character is associated with reproduction and cannot be expressed in the vegetative beet. Therefore, the pollinators of monogerm F_1 hybrids need not be monogerm and this fact alone gives the breeder a great deal of flexibility. The pollinator of the F_1 hybrids may be any available multigerm variety or any beet, in fact, which possesses high combining ability, the required disease resistance, etc.

One objective of producing an F_1 monogerm hybrid was to supply the sugar beet industry with monogerm hybrid seed for mechanization studies. This work will be reported by other investigators. The present paper deals with yielding ability, curly top disease resistance and sugar content. Three F_1 monogerm male-sterile hybrids are reported which were developed very rapidly from the first available monogerm stocks.

Material and Methods

In the spring of 1949 three well established type 0 (3) curly-top-resistant multigerm clones were hybridized with pollen supplied by Dr. V. F. Savitsky from his first monogerm beet SLC 101 (4). The term type O refers to the ability of a pollinator to produce F_1 populations, all individuals of which are completely emasculated in hybrids to cytoplasmic male steriles. It was soon learned that SLC 101 was not perfect with respect to type 0 but it approached the desired genetic constitution. In hybrids to male steriles SLC 101 usually produced some F_1 offspring which were classed as semi-male sterile, but without viable pollen.

The F_1 *Mm* hybrids between type 0 multigerm beets and the SLC 101 monogerm beet were grown for seed and F_2 populations were produced in 1950. In the same seed isolation F_1 *Mm* male sterile hybrids (MS x SLC 101) were also included. The isolation therefore produced two F_2 populations, one with normal cytoplasm and one with the S cytoplasm responsible for cytoplasmic male sterility (2). From each of these F_2 populations 3:1 segregation was observed for multigerm versus monogerm beets. In 1951 the multigerm segregates from these populations were eliminated by roguing in the bud stage and the process was repeated with some refinements in 1952. In separate isolations in 1951 and 1952, monogerm male sterile beets were also crossed to other multigerm pollinators for production of vigorous F_1 hybrids. The following descriptions apply to the hybrids discussed in this report.

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[2] Numbers in parentheses refer to literature cited.

Hybrid 120H15 was made by crossing monogerm male sterile beets obtained from the first backcross to SLC 101 with SL 120 as the pollinator. SL 120 was selected for very high curly top resistance from the commercial variety U. S. 22/3. This brought about some reduction in sugar percentage. The F_1 hybrid 120H15 was therefore expected to be good in curly top resistance but perhaps not too good in sugar content.

Hybrid 202H15 was made in 1952 by crossing the monogerm male sterile segregates produced in 1951 to the multigerm strain SL 202 as the pollinator. SL 202 is high in curly top resistance and is higher in sugar percentage than SL 120, an improvement brought about by utilizing the high sugar variety U. S. 35/2 in its development.

Hybrid 211H15 was also made in 1952 by utilizing the same monogerm male sterile with SL 211 as the pollinator. SL 211 was the direct offspring of two of the type 0 multigerm clones with which SLC 101 was hybridized in 1949. Therefore, the production of hybrid 211H15 represents rather close breeding and some reduction in vigor was expected.

The male sterile monogerm hybrids were compared with the well known curly-top-resistant variety U. S. 22/3 (seed lot SL 96) and also with the multigerm hybrid SL 944H1. This later hybrid was made by utilizing a male sterile equivalent of the curly-top-resistant inbred CT9 with SL 944

Table 1.—Results from Variety Tests in 1952 and 1953 Comparing Monogerm Male-Sterile Hybrids with the Commercial Variety U. S. 22/3 and the Multigerm Hybrid SL 944H1.

Variety	Monogerm or multigerm	Gross sugar per acre		Tons beets per acre	Percent sucrose
		Percent of U. S. 22/3	Pounds		
Shelley and Twin Falls, Idaho, 1952, 6[1] replicated plots each variety					
120H15	Monogerm	100	8,916	26.6	16.76
U. S. 22/3	Multigerm	100	8,915	26.5	16.82
944H1	do.	108	9,604	28.0	17.15
Taylorsville, Utah, 1952, 6 replicated plots each variety					
120H15	Monogerm	100	12,022	41.8	14.38
U. S. 22/3	Multigerm	100	11,984	43.2	13.87
944H1	do.	108	12,920	45.3	14.26
Twin Falls, Idaho, 1953, 5 replicated plots each variety					
202H15	Monogerm	106	11,290	33.6	16.80
211H15	do.	97	10,299	31.4	16.40
U. S. 22/3	Multigerm	100	10,630	31.6	16.82
944H1	do.	108	11,517	34.9	16.50
Taylorsville, Utah, 1953, 5 replicated plots each variety					
202H15	Monogerm	110	11,880	39.6	15.00
211H15	do.	107	11,471	37.1	15.46
U. S. 22/3	Multigerm	100	10,760	39.5	13.62
944H1	do.	115	12,364	42.4	14.58
Granger, Utah, 1953, 5 replicated plots each variety					
202H15	Monogerm	106	11,427	33.6	17.02
211H15	do.	93	10,102	29.4	17.18
U. S. 22/3	Multigerm	100	10,824	32.8	16.50
944H1	do.	108	11,689	35.9	16.28

[1] In 1952 results from 3 replications grown by the Utah-Idaho Sugar Company at Shelley, Idaho, were combined with results from 3 replications grown at Twin Falls, Idaho.

as the pollen parent. SL 944 was a curly-top-resistant strain not greatly different from U. S. 22/3. The hybrid SL 944H1 usually performs better than U. S. 22/3. These two standards, U. S. 22/3 and SL 944H1, should illustrate the comparative yielding ability of the new male sterile monogerm hybrids.

Yield Comparisons

Results tabulated in Table 1 show practically the same yielding ability for the monogerm hybrid 120H15 and the commercial variety U. S. 22/3 in the 1952 tests. In 1953 the monogerm hybrid 202H15 showed an increase of 6 to 10 percent in gross sugar per acre as compared with U. S. 22/3. As expected the monogerm hybrid 211H15 was inferior in yielding ability but perhaps not as much so as might have been expected due to the close breeding used in its development. These results indicate that monogerm male sterile hybrids, equal in yielding ability to the commercial variety U. S. 22/3, may be readily produced from breeding stock now available. Further breeding work may be required to produce monogerm male sterile hybrids equal to the better multigerm curly-top-resistant hybrids which are now being propagated.

Curly Top Evaluations

Previous work (1) has shown that F_1 hybrids between culy-top-resistant and curly top-susceptible stocks are intermediate in degree of curly top resistance. However, when one parent is high in resistance and when the disease is only moderate in degree, the degree of resistance in the hybrid is fully dominant or nearly so. In variety tests reported in Table 1 curly top was encountered at all locations in 1952 but the F_1 monogerm hybrid 120H15 showed no curly top injury. Again in 1953 there was considerable curly top in the susceptible Klein E variety in the test at Twin Falls, Idaho, but nothing more than a trace of the disease was evident in the monogerm hybrids 202H15 and 211H15.

Under an artificial curly top exposure conducted at Jerome, Idaho, in 1952 the monogerm hybrid 120H15 showed good curly top resistance, but not quite equal to that of U. S. 22/3. In 1953 the curly top exposure at Jerome, Idaho, was much more severe than in 1952 and even the highly resistant commercial variety U. S. 22/3 was severely injured in midsummer plantings. Here in a July 15 planting varieties were graded on an arbitrary basis from 0 to 10 depending upon the degree of resistance. U. S. 22/3 was able to continue growth but was definitely injured; it received grade 7. The monogerm hybrid 202H15 received grade 8. U. S. 33, an old curly-top-resistant variety and widely grown at one time, received grade 10. The best breeding stocks available received grades 4 and 5.

These observations showed that, although the monogerm hybrid 202H15 was slightly lower in curly top resistance than U. S. 22/3, nevertheless it was definitely better than U. S. 33. From this evidence it would seem safe to grow curly-top-resistant monogerm hybrids of this type commercially except where severe disease exposure is expected.

Summary

Multigerm beets emasculated genetically by cytoplasmic male sterility were hybridized with Dr. V. F. Savitsky's original monogerm line SLC 101 in 1949. Subsequent backcrosses to new monogerm pollinators, selected from SLC hybrids, produced relatively good male sterile populations in 1951 and 1952. These monogerm MS populations were hybridized with multigerm beets to produce vigorous F_1 hybrids. One of these F_1 hybrids was evaluated agronomically for yield and sugar content in 1952 and two hybrids were evaluated in 1953. Two of these monogerm hybrids were equal or superior in yield to the commercial variety U. S. 22/3, but produced less in gross sugar per acre than the multigerm M. S. hybrid SL 944H1, made with the curly-top-resistant inbred CT9.

The results indicate that monogerm male sterile hybrids equal in yielding ability to present commercial curly-top-resistant varieties may be readily produced from breeding stocks now available. Further breeding work will be required to produce monogerm MS hybrids equal to the better multigerm curly-top-resistant hybrids which are now being propagated.

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A Monogerm Gene from MW 391

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During the summer of 1950 two monogerm roots of Dr. Savitsky's line SLC 101 were used as pollen parents in producing F_1 hybrids with several of our varieties, one of which was Holly 13, the stock source of our commercial variety MW 391. This F_1 was given the breeding number 011-00C59.

In the winter season of 1950-51 plants of the F_1 011-00C59, and the parental variety, Holly 13, were produced and a backcross was made using the self sterile Holly 13 as the female plant and the self fertile F_1 011-00C59 as the male parent. This backcross was given the breeding numebr 111-00C265.

Stecklings of this backcross were produced during the summer of 1951, given thermal induction in the root cellar, and transplanted to the greenhouse during the 1951-52 winter season for the purpose of self sterility and self fertility classification.

In this segregating population of 700 plants, one plant was found to be monogerm. Since the F_1 plants in the original cross must be assumed to be heterozygous (Mm) for the monogerm gene, then the only possibility for a monogerm plant to appear in the backcross generation would be for one of the Holly 13 plants used in the backcross to be heterozygous for the monogerm gene also. The resulting monogerm plant in the backcross must have obtained one recessive gene from the F_1 parent and the other recessive gene from Holly 13.

This new monogerm segregate has been used in hybridization with several of our breeding stocks during the 1952-53 winter season. Monogerm segregates from these crosses will be studied with interest and should be valuable in our future breeding program.

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Obtaining Tetraploid Monogerm Self Fertile, Self Sterile, and Male Sterile Beets

HELEN SAVITSKY[1]

Introduction

Insofar as inbreds and male sterile lines have been included in breeding work in recent years, it has become important to study the behavior of these breeding stocks in the tetraploid condition. The following subjects aroused special interest:

a. How easily can tetraploid inbred lines be propagated? Is their degree of self-fertility the same as the original diploid lines?

b. Will the manifestation of male sterility remain the same in tetraploid male sterile lines as in diploid lines or is the degree of male sterility increased in the tetraploid condition?

c. What will be the level of heterosis in tetraploid hybrids compared to diploids?

Data concerning the behavior of 4*n* inbred lines are not numerous for different crops. Randolph (5)[2] described a pronounced decrease in vigor and fertility in inbred strains of maize, while tetraploids derived from stocks which had not been inbred were as vigorous or more vigorous than the diploid parents and were highly fertile. Tetraploid plants produced directly from inbred lines were consistently much shorter and less robust than their diploid sibs. They produced few viable seeds, but abundant pollen and well developed ears. The doubling of chromosomes in heterozygous open-pollinated varieties or in hybrids derived from inbred lines produced vigorous, robust and highly fertile tetraploids.

Abegg (1) reported a striking decrease in vigor and fertility in 4*n* self fertile strains of sugar beets. Seeds collected from unbagged branches of colchicine-treated self fertile plants with a high degree of self fertility were assumed to be tetraploid and were compared with related diploid lines in field tests. The second generation of tetraploid progeny from this plant was also tested. A total of 193 tetraploid plants yielded approximately only half as much as the closely related diploid plants. The majority of greenhouse-grown tetraploid plants derived from the highly self fertile diploid strain produced only a small amount of seed under paper bags.

Lundquist (3, 4) indicated a lower inbreeding depression in tetraploids than in the corresponding diploid variety of rye. The inbreeding material was obtained by selfing elite diploid and tetraploid populations of Steel rye. Plant height, number of spikelets and seed fertility were studied. Reaction of diploids and tetraploids to inbreeding was similar for different characters. However, the depression was less in tetraploids. The values for the tetraploids were in all characters and generations beyond those of the diploids.

Material and Method of Treatment

The following sugar beet breeding stocks were exposed to colchicine treatment:

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[2] Numbers in parentheses refer to literature cited.

1. S_2 monogerm self fertile inbred lines NN 509, 600, 602, 610 and 5891.

2. Male sterile monogerm lines N 9563/602, N 24/610, and N 9333/600. Line 9563/602 had male sterile plasma from a mangel variety and was pollinated by the inbred line N 602 during the last two generations. Line N 24/610 had male sterile plasma from curly top-resistant sugar beet variety U. S. 56 and was crossed back in the last generation to inbred line 610. Line N 9333/600 had male sterile plasma from the old high sugar Polish variety Janash; the two last backcrosses were made with inbred line N 600.

3. The first monogerm self sterile beets which were selected in hybrids between the self fertile monogerm SL 101 and self sterile multigerm beets.

Young seedlings were treated with a colchicine solution in the fall of 1952. The cotyledons and the upper part of the hypocotyl were treated by the method described in a previous paper (7). Treatment lasted 6-7 hours. Concentration of colchicine applied was 0.4-0.5 percent.

The seeds were germinated on filter paper. When the tips of the radicles had scarcely appeared the seeds were plunged into an 0.5 percent colchicine solution for five hours. Treated seeds were rinsed in water and planted into pots.

All treated seedlings were grown for two months in a greenhouse and then transferred to a cold frame for thermal induction. They were transplanted into the field in the spring. The inbreds and male sterile beets were grown in one isolation plot, the self steriles in another.

The tetraploid plants in self fertile and self sterile beets were selected according to size of pollen grains. All attempts to distinguish tetraploid plants in male sterile beets by determination of the size of pollen mother cells did not give reliable results. Although pollen mother cells of diploid and tetraploid plants were measured at the same stage of meiosis, authentic data were not obtained because of variability and insufficient differences in cell size. Therefore, male sterile tetraploid plants were selected by the determination of chromosome number at meiosis of the treated plants. The aceto-carmin smear method was used for this purpose.

All selected tetraploid plants were bagged with white paper bags. Several bags were put on every plant. On each $4n$ plant derived from self fertile lines one bag remained for selfing, while all other bags were used for intercrosses between different $4n$ inbred plants and for pollination of $4n$ plants by the pollen of $4n$ self sterile multigerm beets. Male sterile $4n$ plants were crossed by changing bags with $4n$ inbred plants and with $4n$ self sterile multigerm beets. The $4n$ self sterile plants were crossed inter se by exchanging bags and also pollinated by pollen of $4n$ self sterile multigerm beets.

Experimental Results and Discussion

Tetraploid Inbred Lines

Twenty-two tetraploid plants were obtained from inbred lines. All these tetraploids developed normally; many of them showed typical tetraploid characteristics: thick, round, dark green leaves, robust stems and large buds. No dwarf or defective plants were observed among them, but they

were much inferior in pollen production and self fertility compared with plants growing in the same field from the same inbred lines which remained diploid after colchicine treatment.

All tetraploid plants produced from inbred lines could be distributed into three groups according to their fertility characteristics: male sterile, self sterile and plants showing some degree of self fertility. Of these tetraploid plants, 22.7 percent were male sterile (Table 1). Some of them developed small transparent anthers. Others had yellow or brown anthers of normal size which did not dehisce. Examination of the anthers showed that they were practically empty. In some plants no pollen grains in the anthers were observed. The anthers of other plants in this group contained small aborted pollen (9-12μ), together with fragments of pollen grains and among them a few large diploid pollen grains. The destruction of pollen occurred after meiosis because meiosis in these male sterile plants took its normal course as in otther tetraploids. Determination of chromosome number at meiosis showed that these plants were tetraploid.

Table 1.—Tetraploids Produced from Self Fertile Inbred Lines.

2*n* parental line number	4*n* plant number	Anther dehiscence	Pollen accumulation	Percent 2*n* pollen	Fertility characteristics: Seed setting after pollination by: Selfing	4*n* from inbreds	4*n* self steriles	General behavior
600	12:35	no	none	0	none	good	good	Male sterile
600	13-29	no	none	0	none	———	good	do.
5891	14-29	no	none	0	none	poor	inter	do.
5891	14-12	no	none	0	none	———	poor	do.
610	9-29	no	none	0	none	poor	good	do.
610	7-38	yes	small	45	none	inter.	good	Self sterile
602	10-27	yes	small	30	none	inter.	poor	do.
602	10-14	yes	small	70	none	good	good	do.
5891	14-24	yes	small	50	none	———	good	do.
5891	14-26	yes	none	50	none	———	inter.	do.
5891	14-7	yes	small	75	none	———	inter.	do.
5891	14-10	yes	small	80	none	———	inter.	do.
5891	14-9	yes	small	70	none	———	inter.	do.
5891	14-4	yes	small	45	none	———	good	do.
509	No. 1	yes	small	80	none	———	good	do.
509	No. 2	yes	none	80	none	———	inter.	do.
610	7-31	yes	small	40	poor	poor	good	Low or semi-self-fertile
610	8-33	yes	small	90	poor	poor	good	do.
602	9-33	yes	inter.	90	inter.	———	good	do.
602	11-14	yes	large	90	fair	good	good	do.
600	11-12	yes	large	90	good	good	good	do.
5891	14-2	yes	inter.	40	inter.	———	good	do.

The largest group (50 percent) of tetraploids produced from inbred lines consisted of plants which developed a sufficient quantity of good diploid pollen grains but remained self sterile. The quantity of well developed diploid pollen grains varied in different individual plants from 30 to 80 percent; at any rate, the quantity of pollen was sufficient for self fertilization if it could pollinate or the pollen tubes could have grown through the pistils.

A characteristic of this group of plants was that in spite of normally developed anthers many of them did not dehisce, or when they did the pollen did not accumulate in the paper bags. The paper bags which covered the branches did not contain pollen at all, or contained very little. Some of these anthers were examined under the microscope. They showed lumps of pollen grains stuck together and located on the split portions of anthers or on their suface. Many pollen grains germinated directly on the anthers and the pollen tubes reached a comparatively good length.

All the plants of this group were self sterile, but when the pollen of self sterile plants N 10-27 and N 10-14 was used for pollination of other 4*n* plants derived from inbred lines, some seeds were produced.

The third group (27.3 percent) consisted of plants which showed some degree of self fertility. The plants of this group developed a sufficient quantity of good diploid pollen grains. The anthers were yellow and of normal size. The amount of pollen collected from the anthers, as well as the quantity of selfed seed, varied in different plants. Four plants set a few seeds after selfing. Two plants (N 11-14 and N 11-12) had much pollen in the paper bags and the number of selfed seed amounted to 30 and 40 percent.

Observation of the behavior of 22 tetraploid plants derived from self fertile parental plants led to the general conclusion that in spite of normal vegetative development of these 4*n* plants their reproductive ability was much lower than in corresponding diploid inbred lines. Only certain 4*n* plants obtained directly from inbred lines were able to produce selfed progeny. The majority of inbred lines would be lost in the tetraploid condition.

When 4*n* plants derived from inbred lines were crossed *inter se* by exchanging pollinating bags a few seeds were obtained in certain crosses. No difference was observed regarding whether the crosses were made within the limit of the same line or between different lines.

Pollination of some of these 4*n* plants by pollen from a self sterile 4*n* population gave much better results. Seeds obtained from these 4*n* plants were planted in the fall. A total of 67 beets grew from selfed seed and 84 plants were derived from crosses between 4*n* plants.

Tetraploid Male Sterile Monogerm Beets

Sixteen tetraploid plants were produced from three monogerm male sterile lines. These diploid male sterile lines were derived from repeated crosses to self fertile inbred lines and those which were not male sterile became self fertile themselves; the semi-male sterile plants which occurred sometimes in such lines produced selfed seed. Therefore it must be expected that the regularities observed in inbred lines could be applied to male sterile lines, too. Only the degree of homozygosity was not so high in these male sterile lines as in the corresponding inbreds which were used for their pollination.

All tetraploid plants derived from male sterile lines were highly male sterile. They all developed small, transparent empty anthers; not one of them had yellow anthers or developed viable pollen. They set a little more

seed than 4*n* inbred lines when pollinated by pollen from 4*n* inbred lines. In their progeny 53 plants were obtained from crosses to 4*n* inbreds and 75 plants from hybridization with a self sterile tetraploid population.

Tetraploidy might be very important to produce completely male sterile strains. If it can be confirmed in succeeding generations that polyploidy increases the degree of male sterility, such 4*n* male sterile lines could be successfully involved in hybridization for obtaining tetraploid hybrids. Josefsson (2) indicates a high yielding capacity for hybrids between 4*n* stocks in Fodder beets. The 4*n* yellow tankard in comprehensive trials produced 23 percent higher yield of dry matter than its mother line, Svalof yellow tankard; 4*n* Sirius outyielded Svalof Bortfelder by 29 percent and Svalof Ostersundom by 15 percent of dry matter. The selection of crosses between 4*n* families of different origin called "Svalof tetraploid Sirius turnips" will be marketed in the spring of 1953.

Self-sterile Monogerm Tetraploids

Tetraploid plants were obtained from the first self sterile monogerm lines. Production and activity of pollen in these 4*n* plants was much higher than in 4*n* beets derived from inbreds. All plants produced a sufficient quantity of well developed diploid pollen grains. The anthers were large, yellow, dehisced in a normal way, and the paper bags used for controlled pollination always contained a sufficient quantity of pollen.

The seed set after exchanging pollinating bags with other tetraploid self sterile monogerm and multigerm plants was much more abundant than from 4*n* inbredls or 4*n* male sterile beets. The seeds were more viable, their germination rate was higher and the offspring were more vigorous. The monogerm self sterile tetraploids were not different from multigerm self sterile tetraploids in the production of a sufficient quantity of pollen and in seed setting ability.

Self sterile multigerm tetraploids recently developed by the above described method from strains SL 824 and SL 92 and Swiss Chard differed very much from the tetraploids obtained at Hilleshog, Sweden. According to Rasmusson (6), tetraploid sugar beets obtained by dipping young flower stalks in colchicine solution were much inferior in their vitality and productivity in their first generations than parental diploid strains. Every 4*n* type was usually derived from two first colchicine treated plants.

Using designations c_1, c_2 etc., to indicate generations of propagation after colchicine treatment, the number of c_1 plants was very small and their seeds were not comparable to the normal diploid seeds. It was also difficult to produce c_2 seeds. Therefore, no attempts were made to try out any field trials. Only c_3 seeds could be produced under normal conditions and in lots large enough to allow testing of 4*n* types. Only those strains were used for tests which had at least 15 plants in the c_1 generation. The leaf color of the first tetraploids was much lighter than in diploids; the difference began to disappear in the c_3-c_4 generation and the old tetraploids had nearly the same color as diploids. The artificial tetraploids started as very inferior types but automatically their original low productivity was improved in later generations (from c_3 to c_5 and c_6) so much that they reached at least the level of comparable diploids.

The effect of hybridization in tetraploid material was considerably greater than in diploids and some of the new tetraploid strains developed from 4*n* bulk crosses were superior to all diploid strains and even to the best diploid bulk crosses.

The tetraploid population of strain SL 824 was developed at Salt Lake City on the basis of 50 c_0 plants and the tetraploid population from strain SL 92 on the basis of more than 40 c_0 plants. The plants of the first generation after treatment (c_1) produced so much seed under open pollination that tetraploids from strain 824 could be tested in 5-6 replications on three different fields in the usual variety tests. The beets in plantings of both tetraploids were well developed, very uniform and showed very pronounced tetraploid characteristics: large, thick, dark-green leaves. Small or dwarf plants could be observed as a rare exception. Both tetraploids were developed from curly top-resistant diploid strains and maintained the same high degree of resistance in the tetraploid condition.

Production of pollen in c_0 plants was inferior to that in diploids, but sufficient, and this improved in the following c_1 and c_2 generations. The quantity of seed set in c_1 and in the next generations under normal field conditions was practically normal. The seedballs were larger than in diploids. The tetraploids showed a little sterility due to abnormalities at meiosis and formation of a certain amount of nonviable gametes, but the quantity of seed set was always abundant, starting from the first generation. The size of tetraploid populations grown was limited by economics only, not by the vitality of tetraploids.

The data for two years' variety tests (Table 2) indicated that tetraploids produced from SL 824, in spite of lower stand, outyielded in different trials its diploid mother strain from 8 to 18 percent. But the loss in sucrose was considerable, especially in the Salt Lake City test in 1953. The increase in yielding ability in tetraploids was obvious but the data indicated the necessity of breeding work in tetraploids to increase the sucrose percentage.

Table 2.—Yield Test of 2*n* SL 824 and 4*n* 824.

		Twin Falls, Idaho		Salt Lake City, Utah			
		1953		1953		1952	
		Absolute figures	Percent of 2*n* SL 824	Absolute figures	Percent of 2*n* SL 824	Absolute figures	Percent of 2*n* SL 824
Beets per 100 feet of row	2*n*	106	100	109	100	62	100
	4*n*	100	94	97	89	74	119
Tons beets per acre	2*n*	29.4	100	35.1	100	22.2	100
	4*n*	31.8	108	39.0	111	26.1	118
Sucrose percent	2*n*	17.4	100	14.9	100	14.9	100
	4*n*	16.1	92	13.4	89	14.1	95

F_1 Hybrids Between a 4*n* Inbred Line and a 4*n* Self-Sterile Beet

Two tetraploid plants, N 1 and N 2 in the monogerm S_3 inbred line N 509, were obtained one year earlier. Because of their complete self sterility and the absence of pollen in the paper pollinating bags they were pollinated

by pollen from 4*n* self sterile beets. The F_1 plants demonstrated striking hybrid vigor. These seed beets were very tall, with large leaves and very thick robust stems. The fruits, like diploid F_1 hybrids between monogerm and multigerm beets, were multigerm (mostly doubles) with a few monogerm seed on the ends of the branches. Examination of pollen from these F_1 plants showed big differences among different plants. All F_1 plants could be classified on quality of pollen into three groups (Table 3). The group with poorly developed pollen consisted of three plants. The plants of this group failed to develop normal pollen grains. The anthers contained a few large pollen grains among fragments and small, aborted pollen. The paper pollinating bags which covered the branches had practically no pollen.

Table 3.—Distribution of F_1 Tetraploid Plants According ot Quality of Pollen.

Poor pollen group			Intermediate pollen group			Good pollen group		
Plant No.	Amount of pollen accumulated	Percent 2*n* pollen	Plant No.	Amount of pollen accumulated	Percent 2*n* pollen	Plant No.	Amount of pollen accumulated	Percent 2*n* pollen
1-4	none	10	1-1	intermediate	40	1-2	large	90
1-12	small	1	1-5	none	50	1-3	intermediate	90
1-14	small	1	1-7	intermediate	70	1-6	small	90
			1-8	intermediate	50	1-9	large	95
			1-10	intermediate	50	1-17	large	96
			1-11	intermediate	55	1-10	large	95
			1-13	intermediate	60	1-20	intermediate	93
			1-15	small	25	1-21	large	95
			1-16	small	60	2-1	large	95
			1-18	intermediate	50			

Ten plants of the second group showed satisfactory development of pollen. The quantity of well developed diploid pollen grains varied in different plants from 25 to 70 percent. For the majority of plants it approached 50 percent. The remaining pollen consisted of small, mostly aborted pollen grains. Seven of the ten plants in this group had a sufficient amount of pollen in the paper pollinating bags.

The third group consisted of nine plants which developed excellent uniform diploid pollen. The quantity of well developed pollen exceeded 90 percent in all plants. Six of the nine plants in this group had abundant pollen in the paper bags, two plants had a sufficient amount, and only one contained a scarcity of pollen in the bag.

Thus, from 22 tetraploid F_1 plants 19 developed a sufficient quantity of good viable pollen grains and 15 of them (four having scant pollen in the bags being excluded) contained much or a sufficient amount of pollen in the paper bags to provide for selfing or cross fertilization. In spite of this, all F_1 plants except one (N 1-3) remained self sterile. The diploid F_1 hybrids between self fertile and self sterile beets were always self fertile. When these F_1 plants were crossed by exchanging paper bags *inter se* they showed almost complete cross incompatibility. Some cross combinations remained completely sterile, while the largest number set 2, 3 or 4 fruits in the large paper pollinating bags and only two combinations set 15 and 20 fruits in several hundred flowers. Six of the F_1 plants were isolated in a separate greenhouse. These six vigorous plants set only 3 grams of seed under open pollination.

Certain F_1 tetraploid plants were pollinated by pollen from self fertile and self sterile diploid plants, the others by pollen from self sterile tetraploid plants. In all cases the quantity of seed set was sufficient or good. This indicates that a sufficient number of female gametes with diploid or close to a diploid number of chromosomes were formed and that the disturbances at meiosis were not so great as to cause an insufficient activity of pollen grains. Rather, some other factors were responsible for the inactivity of male gametes in F_1 hybrids.

The same F_1 tetraploid plants which were self incompatible and cross incompatibile with other F_1 tetraploid plants were compatible when pollinated by pollen from unrelated self sterile or self fertile diploid and tetraploin plants. Thus F_1 progeny between self fertile and self sterile tetraploid plants formed a self sterile and inter sterile group.

The behavior of these F_1 tetraploid plants could be explained on the basis of the oppositional factor hypothesis. The genetype of $4n$ F_1 plants regarding fertility versus sterility factors could be $S^f\ S^f\ S^1\ S^2$. These F_1 plants would produce four types of gametes in the ratio: 2-$S^f\ S^f$, 4-$S^f\ S^1$, 4-$S^f\ S^2$, 2-$S^1\ S^2$. Gametes with $S^1\ S^2$ factors could not grow through the pistils of F_1 plants because of the presence of $S^1\ S^2$ factors in the pistils.

Gametes $S^f\ S^1$ and $S^f\ S^2$ might produce fertilization in some cases if the presence of one factor, S^f, in the pollen grain could compensate for the negative action of the factor S^1 or S^2. In F_1 diploid hybrids between self fertile and self sterile beets, the pollen grains which carry one factor S^f are effective on the pistils with one S^f factor ($S^f\ S^1$). Whether two S^f factors in the pistil of F_1 tetraploid plants will permit the pollen grains with one S^f factor to grow through it is not quite clear now, but this possibility may be expected and in such cases a few seeds may be produced sometimes by selfing or in inter-crosses of F_1 $4n$ hybrids. However, the experimental data do not indicate that the pollen grains of any genetic structure were successful in selfing or in sib crosses in F_1 $4n$ plants.

It was obvious that the pollen grains which carried two S^f factors were also not stimulated on the pistils with two S^f factors ($S^f\ S^f\ S^1\ S^2$). The experimental data obtained are in agreement with the oppositional factor hypothesis. This hypothesis explains the behavior of all F_1 plants except one which was semi-self-fertile. The most probable explanation of the partial self fertility in this plant may be the assumption that it carried in its genotype some genes independent from the *S* series which caused an intermediate degree of self fertility of an associated type. There is also the possible assumption of alteration in action of certain genes of the *S* allelic series in consequence of mutation, deletion or duplication.

If the phenomenon of self and cross incompatibility in $4n$ F_1 hybrids between self fertile and self sterile beets can be confirmed, then the possibility arises of using such F_1 $4n$ hybrids in double crosses for obtaining $3n$ and $4n$ hybrids.

The self sterility or very low seed production by selfing or inter-crossing $4n$ inbred plants was a general observation. With few exceptions all plants were practically self and cross incompatible. It is possible that the growth of pollen tubes with two S^f factors was prevented as a rule on the stigma with four S^f factors. But the existence of rare tetraploid plants which showed self fertility arouses suspicions as to whether self and cross incom-

patibility in tetraploid inbred plants were also caused by some other phenomena besides the relation between factors of the *S* allelic series in the pistil and in pollen grains. Among these other phenomena, the general low vitality of pollen grains carrying two S^f genes or the accumulation of a number of identical homozygous genes in 4*n* inbred lines could be mentioned. Further cytogenetic investigation of tetraploids is necessary to make final conclusions.

Summary

Tetraploids were obtained in mongerm self sterile, self fertile and male sterile sugar beets. The self sterile monogerm tetraploids did not differ from the multigerm self sterile tetraploids obtained previously. They developed more viable pollen than tetraploids obtained from self fertile inbred lines. Seed setting and germination of seeds were better in 4*n* self sterile plants than in 4*n* inbreds or in 4*n* male sterile plants.

All 4*n* male sterile beets were highly male sterile. They set some seeds when pollinated with 4*n* self sterile beets and with 4*n* self fertile inbreds.

The quality of pollen in tetraploid inbreds was lower and the ability for self fertilization decreased in comparison with diploid plants from the same in bred lines. Some of the 4*n* inbred plants became male sterile, while the majority of them were self sterile and only a few set some seeds after selfing.

The first hybrid generation between 4*n* self fertile and 4*n* self sterile plants, contrary to the corresponding self fertility of diploid F_1 hybrids, was self incompatible, and cross incompatibility was observed in sib crosses. The behavior of F_1 4*n* plants might be explained on the basis of the oppositional factor hypothesis.

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General Combining Ability of Sugar Beet Inbreds as Determined with Two Different Top Cross Testers

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An economical method for the production of hybrid seed for testing general combining ability is needed if a multiplicity of sugar beet inbred lines are to be tested. The cost of converting all inbred lines to cytoplasmic male sterile equivalents or providing an isolation plot for each inbred for the production of hybrid seed would be prohibitive and would result in a serious limitation on the number of lines tested.

Investigation has shown that the ranking of inbred lines of corn for general combining ability can best be accomplished through the use of tester stocks which have a broad genetic base (3) (5)[2].

For sugar beet inbreds, a top cross tester variety having a dominant characteristic which would easily identify hybrid seedlings could be used for self sterile inbred lines (7). Deming (1) obtained significant differences between top cross progeny as to tonnage and total sugar using a red beet tester. Red garden beets have a dominant marker but a question has arisen as to whether the variety would be a reliable top cross tester inasmuch as the leaves are heavily pigmented and the yield of roots and sugar content are very low as compared to sugar beets. To resolve this question, the study reported here was devised whereby the top cross performance of inbreds using a red beet half sugar variety as a tester was compared with the top cross performance of the same inbreds using a commercial sugar beet variety as a tester.

In conjunction with the top cross testing some information was obtained as to the relationship of inbred performance to top cross performance.

Materials and Methods

A group of inbred lines with green hypocotyl from the 1951 Inbred Performance test (8) was tested for general combining ability utilizing a commercial sugar beet variety and a red beet variety as the tester parents. The red beet variety, originally acquired from Germany, was unique because it could be considered a half-sugar type and because of the similarity of its root shape to the sugar beet. Roots of the sugar beet tester were red hypocotyl so that hybrids with the green hypocotyl inbreds could be identified, red being dominant over green.

A separate isolation plot was used for each tester parent. Roots from the green hypocotyl inbred lines were planted in both plots in alternate rows with roots of the top cross testers. The isolation plot for the red beet tester contained roots from red hypocotyl lines also. Seed was harvested from the inbreds by line.

The percentage of seedlings bearing the marker characters was calculated at the time germination percentages of the top cross seed lots were determined. A great diversity between lots as to percentage of identifiable hybrids was found due in part to different flowering dates and in part,

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[2] Numbers in parentheses refer to literature cited.

no doubt, to different degrees of self fertility existing between inbred lines. This diversity of hybrid percentages was also observed by Deming (1).

Planting rates were adjusted so that at least six hybrid germs were planted per foot of row. The design of the test was a triple lattice having 64 entries and six replications. The two test parents were included as entries. The individual plots consisted of six rows 22 inches in width and were 23.3 feet long. The plots were thinned to known hybrids as indicated by red hypocotyl for entries having a commercial top cross parent and red leaves for entries with a red beet parent.

At harvest the plots were trimmed to competitive beets. Six rows per plot, not exceeding 18 feet in length, were harvested for weight determinations with beets from two of these rows being analyzed for sugar percentage.

Seedling disease, following a dashing rain and hail, took a heavy toll in the plots. A near minimum number of hybrid seedlings coupled with the seedling disease resulted in the stands of some plots being reduced below a figure necessary for reliability of results. Following the calculation of the analysis of variance, those entries in which the harvested stand fell below 50 percent were disregarded for the calculation of the correlation coefficient.

The association of the results from the use of the two top cross parents for determining general combining ability was expressed as a correlation coefficient. There were reliable data for only 16 comparisons.

Correlation coefficients were also calculated to determine the association of combining ability as measured by the red beet tester with inbred performance records for the 31 inbreds used in this comparison were taken from the Longmont test of the 1951 Inbred Performance Test (8).

Correlation coefficients were calculated for total sugar and its components, tonnage and sugar percentage.

Discussion of Results

A comparison of the use of a red beet tester parents and a commercial tester parent for measuring general combining ability is summarized in Table 1.

Table 1.—Association of Top Cross Performance of Sugar Beet Inbreds Using a Sugar Beet Tester with Top Cross Performance Using a Red Beet Tester for 16 Comparisons.

	Tons per Acre	Sugar Percentage	Pounds Sugar per Acre
Sugar Beet	21.4	13.2	5,629
Red Beet	20.6	10.7	4,367
C.V.[1]	8.23	5.76	10.05
r	.67[2]	.79[3]	.52[2]

[1] Coefficient of variability of the whole test from which the comparisons were extracted.
[2] Significant at the 5 percent level of probability.
[3] Significant at the 1 percent level of probability.

The correlations, $r = .67$ for tons per acre and $r = .79$ for sugar percentage are slightly but significantly higher than the correlation, $r = .52$, for their product, sugar per acre. A correlation coefficient of .47 is necessary for significance at the 5 percent level of probability and .59 for the 1 percent level of probability. Errors for both tonnage and sugar content are confounded in total sugar and would be expected to be reflected in the correlation coefficient.

More confidence could be placed in these results if the rank association as measured by the correlation coefficient was higher and the number of comparisons was greater. The results do indicate, however, that rather satisfactory predictions could be made using either of the two top cross testers.

Both tester varieties have a broad genetic base; however, the base for each of the two varieties is quite different. Because of this difference in genetic base, some expression of combining ability specific for the two varieties would not be unexpected. However, with the limited number of comparisons available for analysis it would probably not be possible to demonstrate a significant tester by line interaction.

The reliability of one tester over another for measuring general combining ability of sugar beet inbreds will be determined only after specific hybrids of inbreds have been tested. Perhaps the use of several testers will be required for efficient evaluation of inbreds for combining ability. Inasmuch as the red beet as a top cross tester gives results reasonably comparable to a commercial variety used as a tester, the ease of manipulation warrants its use as a tester stock for determining general combining ability, particularly at this early stage of the inbred-hybrid program.

The correlation existing between top-cross and inbred performance was expected (Table 2). For this comparison the red beet was used as the tester parent. The correlation, $r = .37$, is more than necessary for significance, at the 5 percent level, between tonnage of the top cross and the tonnage of the inbred and is similar in magnitude to the correlations for yield in corn inbreds and top crosses. The works of Nilsson-Leisnner (6), Jorgenson and Brewbaker (4) and Jenkins (2) all showed an association between inbred yield and hybrid yield in corn. This association, however, was rather weak.

Table 2.—Association of Top Cross Performance Using the Red Beet Tester with Inbred Performance for 31 Comparisons.

	Tons per Acre	Sugar Percentage	Pounds Sugar per Acre
TC Red Beet	20.9	10.6	4,396
Inbred	18.3	16.7	6,097
TC Parent	18.5	6.9	2,335
Inbred, adjusted	17.0	13.7	4,670
C.V. %, T.C. test[1]	8.23	5.76	10.05
C.V. %, Inbred test[1]	13.15	3.14	13.52
r	.37[2]	.68[3]	.43[2]

[1] Coefficient of variability of the whole test from which the comparisons were extracted.
[2] Significant at the 5 percent level of probability.
[3] Significant at the 1 percent level of probability.

The correlation between the sugar percentages of the inbreds and the sugar percentage of their top cross progenies, $r = 68$, is more than necessary for significance at the 1 percent level. This correlation is high compared to the correlation existing for tonnage, $r = .37$. The close association between the sugar content of inbreds and their top cross progeny suggests that the genes which condition sugar percentage exhibit little or no dominance and are additive. By a rough comparison through the commercial check varieties in both tests the average sugar percentage of the

inbreds tested would have been 13.7 percent had they been included in the same test with the top cross hybrids. The average between this figure and the sugar percentage of the top cross parent (6.9 percent) is 10.3 percent,or very close to the average sugar content of the top cross hybrids (10.6 percent). If dominance exists it is probably negligible. The same type of observations have been made at this Station in connection with hybrids between high and low sugar content varieties, and have always resulted in an intermediate sugar content. Further evidence that dominance is not a primary characteristic of genes conditioning sugar percentage in sugar beets is the lack of depression in this character as inbreeding progresses.

The association of the total sugar produced by the inbreds and their top cross progeny, $r = .43$, which is more than necessary for significance, at the 5 percent level, reflects the low correlation for tonnage for the same comparison and to some extent the error attached to both the tonnage and sugar percentage figures.

In regard to selection of inbreds, the data from this test would indicate that relatively more is to be gained from selection for sugar percentage than for tonnage if it is assumed that inbreds will react in hybrids with other inbreds as they react in hybrids with varieties.

Additional information concerning combining ability will be available as the use of the top cross testing continues and as hybrids from inbreds are produced. Information as to the behavior of the various disease reactions and chemical characters relative to combining ability will greatly aid the development of inbred lines which will be of value in hybrids.

Sugar beet breeders as they approach the inbred-hybrid program are very fortunate in having at their disposal the large reservoir of information compiled by the corn breeders. Breeding problems in sugar beets will be more easily solved because of this information and the speed of improvement might well be greater than for corn.

Summary

1. The association of combining ability of 16 inbreds as measured by a commercial sugar beet variety tester and by a red beet tester was $r = .67$ for tonnage, $r = .79$ for sugar percentage and $r = .52$ for total sugar. These figures, which were statistically significant, were taken as evidence that the reliability of the red beet tester was sufficient to warrant its use, particularly when its ease of manipulation for making hybrids is considered.

2. The association of combining ability of 31 inbreds as measured by the red beet tester and the performance of the 31 inbreds was $r = .37$ for tonnage, $r = .68$ for sugar content and $r = .42$ for total sugar. These data indicate that the sugar percentage of the inbred will determine to a large extent the sugar percentage of the hybrids of which they are a component. The behavior of sugar percentage in hybrids would lead to the conclusion that genes conditioning sugar percentage are additive and exhibit little or no dominance.

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Hybrid Sugar Beets Made by Utilizing Both Cytoplasmic and Mendelian Male Sterility

F. V. OWEN[1]

Cytoplasmically inherited male sterility enables the breeder to produce a population with all individuals effectively emasculated. Mendelian male sterility is less attractive for large scale hybridization work because 50 percent male sterile individuals is the maximum which is normally expected. This 1:1 ratio of normal pollinators to male steriles is obtained in backcross populations. In F_2 or succeeding generations after selfing, 3:1 ratios may be expected. The necessary roguing work during the bud stage to eliminate pollen producers in these segregating populations seemed at first to preclude the use of Mendelian male sterility in the production of commercial hybrid sugar beets. For several years, however, the writer has been utilizing Mendelian male sterility as a means of emasculation for several types of genetic and breeding investigations where extensive roguing has not been necessary (1)[2].

In 1951 the discovery of a gene for Mendelian male sterility in the high-sugar curly-top-resistant variety U. S. 35/2 excited interest in wider applications. A backcross population of U. S. 35/2 was produced which segregated for 50 percent male sterility in 1953. Roguing out the pollen producers proved an easier task than anticipated. Consideration can now be given to production of a 4-way hybrid (A x B) x (C x D) in which A and A.B carry cytoplasmic male sterility. The male sterile grandparent C must be obtained by roguing out pollen producers in segregating populations. This leaves a wide latitude in selection of the D pollinator. For the production of one acre of hybrid seed, one pound of C.D seed (for the pollinator) should be ample for a mixture with 15 pounds of the male sterile A.B (for use as the female parent). If there is real merit in such 4-way hybrids, the scheme should be entirely practical.

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[2] Numbers in parentheses refer to literature cited.

The Relative Performance of Some Non-Rogued Male Sterile Hybrids

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Considerable interest exists among sugar beet breeders in the commercial utilization of hybrid vigor. Several investigators (1, 2, 3, 5)[2] have produced small quantities of experimental hybrid seed and have clearly demonstrated the superiority of hybrids over open-pollinated varieties. The discovery of cytoplasmic male sterility in sugar beets (4) opened the way for commercial utilization of heterosis by providing an effective means of crossing selected strains on a large scale for the production of commercial quantities of hybrid seed.

Further study is needed on several problems associated with cytoplasmic male sterility and the commercial production of hybrid seed. One of these problems concerns the effect on hybridization and yield of semi-male sterile and fertile plants within the male sterile seed parent. At the present time, available curly top-resistant male sterile lines are not completely male sterile. Varying numbers and degrees of semi-male sterile and fertile plants occur within them. Before commercial production of hybrid seed can be undertaken, the frequency and degree of semi-male sterile plants within male sterile strains and their effect upon hybridization must be determined.

This paper deals with the relative performance of two rogued, and two non-rogued, hybrids (top crosses) made by utilizing as seed parents two curly top-resistant male sterile lines which differ appreciably in degree of male sterility. Additional non-rogued top crosses made with a common male sterile seed parent and selected pollen parents are also reported.

Methods and Procedure

Seed of the male sterile strains SL 9090M1 and SL 9031M1 was obtained from the division of Sugar Plant Investigations office in Salt Lake City. SL 9090M1 is the male sterile equivalent of inbred CT9 (SL 9090). SL 9031M1 in an F_1 hybrid between inbreds CT 9 and CT 31.

Seed of each of these strains was planted in August, 1950, at Avon, in Cache Valley, and at Eden, in Ogden Valley. An open-pollinated selection, TF-48, was used as the common pollen parent at both locations. The male sterile strains were planted on opposite sides of TF 48, and occupied approximately .2 acres each at both Avon and Eden. At Eden both male sterile strains were carefully rogued during the flowering period. All semi-male sterile and fertile plants were removed while the flowers were in the bud stage. The male sterile plants at Avon, on the other hand, were not rogued. During the flowering period random samples of the male sterile strains were classified for degree of male sterility.

In July, 1951, the following seed lots were harvested:

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[1] Plant Breeder, Amalgamated Sugar Company, Ogden, Utah.
[2] Numbers in parentheses refer to literature cited.

Variety	Pedigree	Location	Description
1313	SL 9090M1 x TF 48	Eden	Rogued
1314	SL 9090M1 x TF 48	Avon	Non-Rogued
TF 48	Pollen Parent		
1315	SL 9031M1 x TF 48	Eden	Rogued
1316	SL 9031M1 x TF 48	Avon	Non-Rogued

The rogued and non-rogued hybrids were evaluated and compared with the pollen parent at five locations in 1952 field tests.

Three additional non-rogued top crosses were made in separate isolations in the summer of 1951. Reserve stecklings of SL 9090M1 were utilized for the female parent and roots of SL 824, N-50 and T50 as the respective pollen parents. The top cross seed was designated 1323, E26 and E27 respectively. E21 and E22 were made in a similar manner in the summer of 1952. SL 9090M1 was used as the female parent in both cases and the inbred SL 19.2 and C-51-1, a high sugar, low sodium selection out of C47, were the respective pollen parents.

A one-half acre over winter increase of the hermaphrodite SL 9090 and its male sterile equivalent SL 9090M1 was planted in August, 1951, at Plain City near Ogden. The seed of this increase was harvested in the summer of 1952 and designated A2-90 and A2-90H0 respectively. Reserve stecklings from this seed increase together with additional SL 9090M1 stecklings were used to plant a two-acre crossing field at Providence in the spring of 1952. This planting consisted of alternate strips of two rows of SL 824 pollen parent and four rows of SL 9090M1 seed parent. The male sterile plants were classified for degree of male sterility (Table 1) during the flowering period but were not rogued. The hybrid seed produced on the male sterile seed parent was designated 2323. This seed was widely tested in strip plantings and replicated field trials in 1953.

Experimental Results

The differences between SL 9090M1 and SL 9031M1 in degree of male sterility are shown in Table 1. SL 9031M1 has approximately 7.5 percent less male sterile plants and 5.2 percent more normal pollen-producing plants than SL 9090M1. In the semi-male sterile class, which consists of plants with abortive anthers but which may shed varying amounts of viable pollen, SL 9031M1 has 2.3 percent more plants than SL 9090M1.

Table 1.—Percentage of Male Sterile, Semi-Male Sterile and Fertile Plants in SL 9090M1 and SL 9031M1—June, 1951, and SL 9090M1—June, 1952.

Plant Classification	Variety		
	SL 9090M1	SL 9031M1	SL 9090M1 June, 1952
Male Sterile (No Viable Pollen)	93.3	85.8	92.1
White Anthers	79.1	66.1	75.7
Pale Yellow Anthers	14.2	19.7	16.3
Semi-Male Sterile	6.4	8.7	7.3
Fertile (Viable Pollen)	.3	5.5	.6
Number of Plants Examined	667	528	1,103

The average performance of rogued and non-rogued hybrids with respect to gross sugar, root yields per acre and percent sucrose is shown in Table 2. In both cases the differences between rogued and non-rogued hybrids are small and not significant. It is known from previous tests that, in yield of gross sugar and tons of beets per acre, SL 9031M1 is equal to or slightly better than U. S. 22/3. SL 9090M1 on the other hand generally yields approximately 10 percent less than U. S. 22/3 in gross sugar and tons of beets per acre. The comparatively high yield of 1313 and 1314 indicates that effective hybridization took place between SL 9090M1 and TF 48. Further evidence of hybridization cannot be obtained from a study of the sucrose content of the hybrids, since the parental lines are low in percent sucrose.

Table 2.—Performance of Rogued vs. Non-Rogued Hybrids (Top Crosses) in 1952.

		General Means		
Variety	**Pedigree**	**Gross Sugar/A**	**Tons Beets/A**	**% Sucrose**
1313	SL 9090M1 x TF 48 (R)	8,065	25.99	15.47
1314	SL 9090M1 x TF 48 (NR)	8,201	26.37	15.43
TF 48	Pollen Parent	7,843	25.25	15.36
1315	SL 9031M1 x TF 48 (R)	8,888	28.21	15.44
1316	SL 9031M1 x TF 48 (NR)	8,436	27.68	15.13
Difference required for significance (19:1)		681	2.29	.61

(R) = Rogued
(NR) = Non Rogued

The performance of additional non-rogued hybrids expressed as percent of the commercial variety U. S. 22/3 is shown in Table 3. The female parent in each case, SL 9090M1, is the same as in hybrids 1313 and 1314 for which the degree of male sterility is shown in Table 1. The pollen parents, however, represent open-pollinated strains with a considerable range in sucrose content. C-51-1, the pollen parent of E22, is a curly top, high sugar, low sodium selection out of the sugar type variety C47. N-50 and T-50 are selections out of U. S. 22/3 which do not differ appreciably from U. S. 22/3 in sucrose content.

Table 3.—Performance of Non-Rogued Hybrids (Top Crosses) Expressed as Percent of U. S. 22/3.

		General Means		
Hybrids	**Pedigree**	**Gross Sugar Per Acre**	**Tons Beets Per Acre**	**Sucrose**
1323	SL 9090M1 x SL 824	109	107	103
E 22	SL 9090M1 x C-51-1	116	110	105
E 26	SL 9090M1 x N 50	110	109	101
E 27	SL 9090M1 x TF 50	108	108	100
U. S. 22/3—Commercial Check		7,774 lbs.	23.72 tons	16.38%

In all cases the hybrids shown in Table 3 are superior to the commercial variety U. S. 22/3. The increased yield of each hybrid over U. S. 22/3 indicates that effective hybridization took place between the respective

parents. The higher sucrose contents of 1323 and E22 in which high sugar pollen parents were used is further evidence that hybridization was effective.

Table 4.—Comparison of Hybrids 2323 and E21 with Their Respective Parents for Gross Sugar per Acre, Tonnage, and Percent Sucrose.

Strain	Pedigree	Gross Sugar		Root Yield		Sucrose	
		Lbs. per Acre	% of M.P.[1]	Tons per Acre	% of M.P.	%	% of M.P.
2323	SL 9090M1 x 824	9,016	125	26.18	125	17.22	100
SL 9090M1	MS of CT9	7,001	97	20.75	99	16.87	98
824	High Sugar Variety	7,415	103	21.21	101	17.48	102
E 21	SL 9090M1 x A2-19.2	8,328	125	24.18	123	17.22	101
SL 9090M1	MS of CT9	7,042	105	21.06	107	16.72	98
A2-19.2	Inbred Pollinator	6,323	95	18.20	93	17.37	102
Diff. Req. for Sig. (19:1)		1,035		3.16		.45	

[1] M.P. = Mid Parent = $\frac{(P1 + P2)}{2}$

Table 4 shows a comparison of hybrids 2323 and E21 with their respective parents for gross sugar per acre, tonnage and percent sucrose. Both hybrids show a substantial increase over their parents in gross sugar and tons of beets per acre. The sucrose content of the hybrids is approximately the same as their mid-parents $\frac{(P1 + P2)}{2}$. This is in agreement with the observations of others (2, 5) and further demonstrates that the sugar content of hybrids is generally equal to the mean of their respective parents. Again, the fact that the sugar content of the hybrids is approximately equal to the mean sugar content of their parents indicates that effective crossing took place in the seed field.

Discussion

Since the male sterile seed parents SL 9090M1 and SL 9031M1 carry the Sf gene it may be assumed that viable pollen produced from semi-male sterile and fertile plants within these strains would result in a proportionate amount of sib- and self-pollination with a corresponding reduction in the amount of hybridization between the male sterile seed parents and the respective pollen parents. The data show, however, that the differences between rogued and non-rogued hybrids are small and not statistically significant. Furthermore, all non-rogued crosses made with SL 9090M1 as the seed parent exceeded the commercial variety U. S. 22/3 in gross sugar and tons of beets per acre. In cases where higher sugar pollen parents were used the sucrose content of the hybrids was approximately equal to the average sucrose content of the parents, which indicates that hybridization was effective.

It would appear that the number of semi-male sterile and fertile plants present in SL 9090M1 is not sufficient to adversely affect hybridization or yield of the resulting hybrids. Either very little viable pollen was liberated by the semi-male sterile plants or the resulting self- and sib-pollinated seed was unable to compete with the hybrid seed under field conditions.

The results obtained indicate that male sterile strains which possess a degree of male sterility similar to that of SL 9090M1 could be used as female parents for commercial hybrid seed production if the necessary amounts of stock seed could be produced without significantly changing the degree of male sterility. It would seem that, for the present time at least, the commercial production of top cross varieties is feasible and that the resulting hybrid seed would be acceptable by present standards of varietal performance.

Summary

1. The relative performance of two rogued and two non-rogued hybrids (top crosses) and six selected non rogued hybrids are reported.

2. Differences between rogued and non-rogued hybrids of the same pedigree were small and not significant.

3. All non-rogued hybrids were superior to the commercial variety U. S. 22/3 with respect to root yields and gross sugar per acre. The general increase in root yields together with a higher sucrose content for hybrids in which high sugar pollen parents were used indicates that hybridization was effective between the respective parents.

4. Utilization of the better currently available male sterile strains for commercial production of hybrid and top cross varieties appears to be feasible.

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Mixing Various Percentages of the Male Parent Seed With Male Sterile Seed for Hybridization and the Subsequent Effect on the Productive Ability of Hybrids

P. A. Reeve and Sam C. Campbell[1]

Within the past few years, the seed growing agencies of the sugar companies have been faced with the possibilities of producing rather large quantities of commercial male sterile hybrid seed by the method of planting the male sterile line and its pollinator in alternate strips in the seed field. This method of production, because of the unplanted area separating the male sterile and the male lines, has proven to be considerably more expensive than the production from a solid field planting and more consideration has been given to the production of these hybrids by the method of mixing the planting stock of both lines and planting the seed field in the usual manner.

To determine the productive ability of hybrid seed produced by the method of mixing the planting stock, seed for a trial was produced in two small isolated plats at Salem, Oregon, in 1952. In each seed plot a four-row strip was planted to a mixture of the male sterile and male lines in a 1:1 ratio. A second four-row strip was planted to a mixture of the two lines in a 4:1 ratio. A third four-row strip was planted to the straight male sterile line. The strip of the straight male sterile line was planted in the center of the plots with the mixtures on either side and it was considered that there would be sufficient pollen producers in the mixtures to provide pollen for the male sterile strip.

The male sterile lines used in both plots were developed by H. L. Kohls of Michigan State College. In one plot the male sterile line planted was that used to produce Hybrid 148, and in the other plot the male sterile line planted was that used to produce Hybrid 125. The percentage of male sterility in the parent for Hybrid 148 was 94 percent and the percentage for the parent for Hybrid 125 was 77 percent. The male sterile strips were not rogued.

The male line used in both plots was U. S. 226, a leaf spot-resistant variety used principally with U. S. 216MS to make the variety U. S. 216 x U. S. 226, which is used widely in the eastern areas.

The three lots of seed from each plot were harvested separately and delivered to Farmers & Manufacturers Beet Sugar Association for inclusion in variety test plots in the eastern sugar beet areas.

Tables 1 through 5 give the yield data secured from these variety tests. These data show that there is no significant difference in yield for the three methods of seed increase.

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[1] Agricultural Supervisor, Farmers & Manufacturers Beet Sugar Association, Saginaw, Michigan, and Manager, West Coast Beet Seed Company, Salem, Oregon respectively.

Table 1.—Harold Kohls Variety Tests—Michigan State College, East Lansing.

Plot Number	Variety	Plants/Acre	Ton/Acre	% Sugar	% Purity
21	50B3	20,036	11.50	19.81	79.58
22	H 125 x U. S. 226	13,799	9.79	16.23	65.88
23	H 125 x U. S. 226 (4:1)	16,837	11.87	19.40	78.35
24	H 125 x U. S. 226 (1:1)	19,031	12.05	19.34	77.82
25	Great Western 359	17,729	11.80	19.87	79.23
26	U. S. 216 x 226	18,688	11.49	19.57	77.80
31	H 148 x U. S. 226	17,797	11.96	19.65	78.22
32	H 148 x U. S. 226 (4:1)	16,953	11.68	19.56	78.06
33	H 148 x U. S. 226 (1:1)	17,317	11.58	19.86	78.43
34	Ac. 345 A01-07	15,764	11.08	19.62	77.69
35	Ac. 345 B01-24	16,815	12.63	20.16	79.16
36	U. S. 216 x 226	17,651	10.84	20.34	79.81

Table 2.—Farmers & Manufacturers Beet Sugar Association Variety Tests—Fred Black Farm, Bay City, Michigan.

Entry No.	S. P. Variety and Local	Acre Yield		Sucrose	Apparent Purity Coeff.	Plants per Acre
		Gross Sugar	Roots			
		Pounds	Tons	Percent		Number
4	H125 x U. S. 226 1:1	5,818	16.515	17.63	79.35	15,947
5	H125 x U. S. 226 4:1	5,851	16.272	17.97	79.79	16,303
3	H125 x U. S. 226 Hyb	5,881	16.644	17.71	79.95	15,947
7	H148 x U. S. 226 1:1	5,710	15.510	18.38	81.13	15,655
8	H148 x U. S. 226 4:1	5,309	14.732	17.96	80.69	16,076
6	H148 x U. S. 226 Hyb	5,551	15.251	18.16	82.12	15,460
1	Amer. 3 N	6,031	16.353	18.42	80.59	16,174
2	Midwest 111	4,852	13.144	18.47	81.11	15,817
	U. S. 400	6,090				
	General Mean	5,625	15.552	18.09	80.59	15,922
S. E. Variety Mean		217	0.536	0.27	0.76	786
S. E. Variety as % of General Mean		3.85	3.44	1.50	0.94	4.94
Dif. req. for Sig. (Odds 19:1)		N.S.	1.518	N.S.	N.S.	N.S.

Variance Table

Source of Variation	D/F	Mean Squares			
		Gross Sugar Pounds	Roots Tons	Sucrose Percent	Apparent Purity Coeff.
Between rows	5	1,028,724	.9111	1.6570	7.6253
Between varieties	7	372,334	8.4375	.6288	4.7150
Remainder—Error	35	281,602	1.7206	.4402	3.4529
Total	47				
Calculated F. Value[1]		1.32	4.90**	1.43	1.37

[1] Designated F. Values at 5 percent level with *, and 1 percent level with **.
(Results above are given as 6-plot averages)

Table 3.—H. W. Bockstahler and G. J. Hogaboam, U. S. D. A., Michigan State College Variety Test—E. J. Krauss Farm, Findlay, Ohio.

Entry No.	S. P. Variety and Local	Acre Yield		Sucrose	Apparent Purity Coeff.	Plants per Acre
		Gross Sugar	Roots			
		Pounds	Tons	Percent		Number
7	H125 x U. S. 226 1:1	6,718	17.554	19.18	81.22	14,650
8	H125 x U. S. 226 4:1	6,490	17.218	18.89	81.78	14,073
5	H125 x U. S. 226 Hyb	7,402	18.398	19.17	82.49	14,223
1	H148 x U. S. 226 1:1	6,656	17.612	18.94	81.05	14,105
2	H148 x U. S. 226 4:1	6,420	16.951	18.93	81.21	14,351
6	H148 x U. S. 226 Hyb	6,021	15.925	18.89	80.37	14,489
3	Acc. 1241 (50B3-0)	6,014	15.568	19.39	82.08	15,450
4	U. S. 216 x 226	6,238	15.290	19.24	80.67	13,945
	General Mean	6,403	16.814	19.08	81.36	14,411
S. E. Variety Mean		333	0.836	0.22	0.68	569
S. E. Variety as % of Genera Mean		5.20	4.97	1.16	0.83	3.95
Diff. req. for Sig. (Odds 19:1)		N.S.	N.S.	N.S.	N.S.	N.S.

Variance Table

Source of Variation	D/F	Mean Squares			
		Gross Sugar Pounds	Roots Tons	Sucrose Percent	Apparent Purity Coeff.
Between columns or blocks	7	4,182,675	36.7205	.9914	3.8978
Between rows	7	1,161,343	8.8939	.4419	1.5401
Between varieties	7	1,335,131	9.7582	.2935	4.0470
Remainder—Error	42	887,913	5.5916	.3885	3.6521
Total	63				
Calculated F. Value[1]		1.50	1.75	0.76	1.11

[1] Designated F. Values at 5 percent level with *, and 1 percent level with **.
(Results above are given as 8-plot averages)

Table 4.—H. W. Bockstahler and G. J. Hogaboam, U. S. D. A., Michigan State College Variety Test—W. H. Sabroske Farm, Fremont, Ohio.

Entry No.	S. P. Variety and Local	Acre Yield		Sucrose	Apparent Purity Coeff.	Plants per Acre
		Gross Sugar	Roots			
		Pounds	Tons	Percent		Number
6	H125 x U. S. 226 1:1	8,164	23.508	17.34	80.88	14,124
2	H125 x U. S. 226 4:1	8,050	24.000	16.78	78.98	13,650
7	H125 x U. S. 226 Hyb	7,866	23.295	16.85	78.45	12,374
5	H148 x U. S. 226 1:1	7,650	22.268	17.16	79.39	13,492
3	H148 x U. S. 226 4:1	7,766	22.596	17.19	79.82	12,982
8	H148 x U. S. 226 Hyb	8,106	23.338	17.36	79.90	13,870
1	Acc. 1241 (50B3-0)	8,058	22.900	17.59	81.37	14.610
4	U. S. 216 x 226	7,498	21.320	17.56	79.84	14,088
	General Mean	7,895	22.903	17.23	79.83	13,649
S. E. Variety Mean		290	0.774	0.19	0.76	581
S. E. Variety as % of General Mean		3.67	3.38	1.12	0.95	4.25
Diff. req. for Sig. (Odds 19:1)		N.S.	N.S.	0.55	N.S.	N.S.

Variance Table

Source of Variation	D/F	Mean Squares			
		Gross Sugar Pounds	Roots Tons	Sucrose Percent	Apparent Purity Coeff.
Between columns or blocks	7	2,778,665	22.2829	.9608	18.8023
Between rows	7	1,376,315	11.5719	.3396	9.8202
Between varieties	7	445,960	5.6209	.6921	6.5292
Remainder—Error	42	670,909	4.7919	.2966	4.6161
Total	63				
Calculated F. Value[1]		0.66	1.17	2.33*	1.42

[1] Designated F. Values at 5 percent level with *, and 1 percent level with **.
(Results above are given as 8-plot averages)

Table 5.—American Crystal Sugar Company Variety Tests.

East Grand Forks, Minnesota (A)

Nine Blocks—73 feet by 20 inches, or 1/358 A.

Variety	T/A[1]	% Sugar[1]	Lbs. Sugar/A.	Rank
H-125 x U. S. 226	15.92	16.72	5,359.54	(2)
1 to 1 ratio	15.47	16.62	5,291.81	(4)
4 to 1 ratio	14.98	16.48	5,079.14	(5)
Am No. 3 N	16.08	17.48	5,782.38	(1)
Am No. 3 LSR	15.46	16.93	5,387.13	(3)

[1] Average of 9 blocks
Comments—Good Test

East Grand Forks, Minnesota (B)

Three Blocks—73 feet by 20 inches, or 1/358 A.

Variety	T/A[1]	% Sugar[1]	Lbs. Sugar/A.	Rank
H-148 x U. S. 226	14.39	16.95	4,878.21	(5)
1 to 1 ratio	15.23	16.90	5,147.74	(3)
4 to 1 ratio	14.55	17.23	5,013.93	(4)
Am. No. 3 N	16.08	17.48	5,782.38	(1)
Am. No. 3 LSR	15.46	16.93	5,387.13	(2)

[1] Average of 3 blocks
Comments—Good Test

Rocky Ford, Colorado (C)

Eight Blocks—90 feet by 22 inches, or 1/264 A.

Variety	T/A[1]	% Sugar[1]	Lbs. Sugar/A.	Rank
H-148 x U. S. 226	10.74	13.70	2,942.76	(5)
1 to 1 ratio	13.45	13.60	3,658.40	(1)
4 to 1 ratio	13.38	13.20	3,532.32	(2)
Am. No. 1	12.39	13.60	3,370.08	(3)
Am. No. 2	11.31	14.30	3,234.66	(4)

[1] Average of 8 blocks
Comments—Not very reliable because of a heavy infestation of nematodes.

Rocky Ford, Colorado (D)

Four Blocks—90 feet by 22 inches, or 1/264 A.

Variety	T/A[1]	% Sugar[1]	Lbs. Sugar/A.	Rank
H-125 x U. S. 226	9.28	10.50	1,948.80	(5)
1 to 1 ratio	9.54	11.60	2,213.28	(3)
4 to 1 ratio	9.17	11.20	2,054.08	(4)
Am. No. 1	10.36	13.60	2,817.92	(1)
Am. No. 2	9.65	14.40	2,779.20	(2)

[1] Average of 4 blocks.
Comments—Not reliable because of nematodes.

Cooperative Testing of Inbreds — Three Years' Results — 1951-53

H. E. Brewbaker and C. W. Doxtator[1]

A cooperative program for testing and cataloguing sugar beet inbred lines was initiated in 1951. Some 50 inbred lines and one standard commercial variety were included that year in field tests at three locations, namely: Longmont and Rocky Ford, Colorado, and Sheridan, Wyoming. Analyses were made for a number of chemical charatcers in laboratories of several cooperating agencies. A brief general report (1)[2] was made from the results.

A similar study was conducted at three locations—Sheridan, Wyoming; Shelley, Idaho, and Longmont, Colorado—in 1952 in which 53 inbred lines were tested and three commercial varieties were included as standards. In 1953 two field tests at two locations—Shelley, Idaho, and Longmont, Colorado—included 60 inbred lines and 4 commercial varieties. The decision to increase the number of commercial standards from 1 in 1951 to 3 in 1952, and to 4 in 1953 was based on a general desire for greater accuracy since the results for several characters are calculated to percent of the mean of the standards. By keeping this standard base broad, it should be possible to rate the inbred lines for some characters in categorical values (1 to 10) for separate locations and for different years accurately. Such a system has been developed by FAO (United Nations) for genetic stocks of wheat and rice (2).

In accordance with a suggestion by C. H. Wadleigh relative to ranking of inbreds for specific characters, an anti-log curve was developed by H. L. Bush, and applied to the 1952 results. This curve placed greater emphasis on the better performing strains. As applied to the 1952 data, it appeared doubtful whether this added emphasis on desirable performance would be of any material value to the breeder.

It is not intended that this report will carry in detail the accumulated data for the past three years. These have been made available in reports to all cooperating agencies. Rather, it is expected that this shall be a report of progress, along with some attempt to evaluate the results to date in terms of possible contributions to sugar beet improvement.

Correlation of Characters

This investigation has provided opportunity to study the interrelationship of various characters. A number of such correlations were calculated and presented in the 1951 report (1). From this it was determined that certain character relationships were remarkably alike for different locations, also that the characters of yield, sugar, Na and K were highly correlated from location to location.

Samples from the 1953 Longmont test were evaluated for thin juice purity by the Great Western Experiment Station using a method recently

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[1] Director, the Great Western Sugar Company, Agricultural Experiment Station, and Manager Agricultural Research, American Crystal Sugar Company, respectively.

[2] Numbers in parentheses refer to literature cited.

developed by Brown and Serro (3), and for marc content by Owens and McComb (5) at the Western Regional Research Laboratory. These, along with sucrose, raffinose, Na and K have been correlated in all possible relationships, with values summarized in Table 1.

Table 1.—Correlation Coefficients for 60 Inbred Lines, Longmont, Colorado, 1953 Results.

	Sucrose	Purity	Raffinose	Marc	Na
Purity	.6857				
Raffinose	—.3827	—.0955			
Marc	.5819	.2978	—.2460		
Na	—.8170	—.5231	.2455	—.5772	
K	—.2461	—.3670	.0720	—.2674	.0561

$r = .250$ for significance at the 5 percent level.
$r = .325$ for significance at the 1 percent level.

Marc appears to be positively and rather highly correlated with sucrose, and to a lesser extent with purity. The relationship with raffinose is negative, with a value slightly less than necessary for significance at the 5 percent level.

Thin juice purity is negatively correlated with Na and K.

Other character relationships are for the most part very similar to those given for the 1951 tests (1).

Sugar Beet Improvement Utilizing Inbred Lines

These three years of data on inbred lines provide a fund of information not previously available, which confirm results with corn and other crops, and are very promising for this method of breeding as applied to sugar beets.

Wide variability between lines is shown to exist for both quantitative and qualitative characters. While most lines are reduced in yield of roots, as compared with the standard commercials, several lines appear to be equal in this respect with the commercials. One line, after 5 generations of self fertilization, was at least equal, if not slightly superior, to the best commercial in both yield and sugar content at both locations in 1953. It appears doubtful whether sugar content is affected adversely by selfing, since there were a number of lines which were significantly higher in this respect than the commercial standards. This appears true likewise for other chemical characters.

As would be expected from the progress made in developing varieties resistant to various diseases, such as curly top, leaf spot, rust, Aphanomyces and Fusarium, the inbred lines provide a wide range of reaction to such diseases. Mildew and other diseases will probably also show similar responses when tested on these inbred lines.

Striking observations of near immunity to black aphis and leaf miner were observed on a few inbred lines at Shelley, Idaho. Some variability in response to the sugar beet nematode has been demonstrated, and further search for resistance to nematodes within inbred lines seems desirable.

Just how inbred lines of sugar beets will be used most successfully as a basis for varietal improvement remains to be demonstrated. In a recent article (4) Longquist has further demonstrated a relatively good correlation

for yielding ability between corn inbreds and hybrids between them. This was known to exist years ago. In Longquist's studies, however, certain crosses of low x high yielding lines produced yields equal with high x high combinations. The possibility of using sugar beet inbred lines as commercial varieties is rather remote, but certainly not outside the realm of possibility, judging from the results of these tests of inbreds. It appears much more likely, however, that inbreds will be used in hybrid combination to take advantage of hybrid vigor. Cytoplasmic male sterility offers an attractive possibility for making such hybrids, particularly so if the inbreds are self fertile. In this connection, evidence obtained by the Great Western Experiment Station from indexing a few plants from each of the inbred lines tested in 1951 indicates that most of those lines are either homozygous or heterozygous for the genes basic to cytoplasmic male sterility. With relatively self sterile inbreds, a high degree of crossing might be reasonably expected in a mixed planting of two or more lines, and the utilization of such lines in commercial hybrids might well be expedited by this method. For example, if any experimental hybrid combination of two or more relatively self sterile lines, none of which was available as male sterile equivalents, were found to be desirable, it would take considerable time to convert to male sterility to prepare it for commercial use; whereas, its immediate use might be anticipated by using a mixture of seed of the inbreds as a basis for commercial seed production. Under these conditions a high degree of crossing might be expected if the parental lines were not self fertile, and if they pollinated at essentially the same period of time.

In this enterprise, it is to be expected that those research agencies which are cooperating will have access to material tested, thus affording each such agency a wide opportunity to collect genic material useful in building varieties adapted to any particular set of conditions.

Summary and Conclusions

1. Three years of testing of inbred lines has been conducted as a cooperative undertaking by several research organizations concerned with sugar beet improvement. A total of 163 lines has been tested and catalogued for a number of characters, although the testing for each character has not yet been completed for all lines.

2. Detailed summaries of these tests have been prepared and provided to all cooperating agencies.

3. In contrast with inbreeding in corn and certain other crops, deterioration in yield appears to be less in sugar beets, with some lines being at least equal to the standard commercial varieties used in these tests.

4. While some features are yet to be worked out, and tests for certain characters are incomplete, the results to date indicate this to be a promising approach to the inbred program of breeding.

5. Wide variations between lines for all characters provide the plant breeder with the opportunity to choose such lines for hybridization as will posess the desired characters for any particular set of environmental conditions.

ACKNOWLEDGMENT

Many people and several research institutions have taken an active part in this cooperative program. The senior writer was chairman for the project in 1951 and 1952. The junior writer served as chairman pro tem during most of 1952, and as chairman for the 1953 program. Others who have taken an active part were mentioned in the 1951 Report (1).

For 1952, in addition to the three field tests conducted respectively by the Holly Sugar Corporation, the Great Western and Utah-Idaho Sugar Companies, the following should be mentioned:

Res. to Aphanomyces, Fusarium and Rhizoctonia—Afanasiev, Montana Exp. Sta.
Res. to Root Rot (Aphanomyces)—Doxtator, American Crystal Sugar Co.
Res. to Curly top—Murphy, U.S.D.A.
Res. to Leaf Spot (Cercospora)—Gaskill, U.S.D.A.
Res. to Virus Yellows and sugar beet nematode—Rietberg, Sugar Beet Inst., Bergen-Op-Zoom, Holland.
Glutamic Acid—Hac, International Minerals & Chemical Corp.
Internal root morphology—Artschwager, U.S.D.A.

For the 1952 results a detailed report was prepared by the Great Western Experiment Station and supplied to all cooperators.

For 1953, replicated field trials were conducted at Longmont, Colorado, and at Shelley, Idaho, by the Great Western and Utah-Idaho Sugar Companies, respectively.

Other tests on these lines include:
Res. to Aphanomyces—Doxtator, American Crystal Sugar Company.
Res. to Leaf Spot—Gaskill, U.S.D.A.
Res. to Rust and Mildew—Johnson, Spreckels Sugar Co.
Res. to Fusarium and Rhizoctonia—Gerhold, Colorado A and M College.
Res. to Curly Top—Murphy, U.S.D.A.
Glutamic Acid—Hac, International Minerals & Chemical Corp.
Marc—Owens, Western Regional Research Laboratory, U.S.D.A.

Routine analyses for various chemical characters, including sugar, Na, K and Ca, have been made by the companies conducting the field tests, and by the American Crystal Sugar Co. Raffinose was determined by the Great Western Sugar Co., and also by the American Crystal Sugar Co. Other chemical characters studied by the American Crystal Sugar Co. have been Galactinol and Inositol. Agronomic characters have been recorded for these field tests, and photos have been taken both in color and black and white for all strains included at Longmont, Colorado, during the three years.

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The Effect of Successive Seed Increases by the Overwintering Method on the Non-Bolting Characteristics of Two Relatively Non-Bolting Varieties of Sugar Beets

RUSSELL T. JOHNSON[1]

In recent years, considerable effort has been expended in California in the development of sugar beet varieties which are highly resistant to bolting or production of seed stalks. This characteristic in varieties is highly desirable for varieties to be planted during the winter months of November, December and January or even earlier. When seeding is done early enough so that bolting is heavy, yields are often reduced because of it.

Development of non-bolting varieties presents a peculiar situation. Bolting is undesirable in commercial sugar beet crops because of the yield reduction it causes, so successful efforts have been made to develop varieties highly resistant to bolting (1) (2)[2]. Bolting is essential in the seed fields, however, because it represents the reproductive phase of the beet and is necessary to maintain the variety. Therefore, if a variety were developed so resistant to bolting that plants in it were unable to develop a seed stalk, it would be useless because it couldn't be maintained, even though such a characteristic would be highly desirable in some commercial beet fields.

Some recent occurrences in early planted commercial fields have given rise to a question regarding the duration of successful maintenance of the high degree of non-bolting in varieties. In some cases it seemed as if varieties had deteriorated in the non-bolting quality which they apparently possessed when first developed a few generations previously.

The present method of commercial seed production in sugar beets is to plant the seed fields in August (for non-bolting varieties), and allow the small plants to remain in the ground over winter. Seed stalks are developed and seed produced the following summer. Most of the seed used in California for planting the commercial sugar beet crop is produced in Oregon or California in this manner.

Present open-pollinated varieties are highly heterogeneous, being made up of a wide range of genotypes. Individual plants are highly self sterile so flowers are cross-pollinated. It is conceivable that non-bolting qualities might deteriorate with each successive seed increase if, for some reason, a certain percentage of plants did not produce seed stalks or participate in the reproduction of the variety. This percentage of plants not producing seed would probably be the most definitely non-bolting segment of the population, and, these being eliminated from reproduction, might cause a shift toward less bolting resistance in the variety. Examination of seed fields has failed to demonstrate this as a cause of deterioration in the non-

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[1] Plant Breeder, Spreckels Sugar Company, Spreckels, California.
[2] Numbers in parentheses refer to literature cited.

bolting qualities of varieties. Many counts of plants producing seed stalks in seed fields have indicated that bolting approached one hundred percent in August planted fields.

Usually in seed plots it can be seen that the plants which start to bolt earliest produce the largest seed stalks and consequently are the most prolific. If these early bolting plants constitute that segment of the population which is inherently the least bolting resistant, then it is conceivable that a deterioration in non-bolting qualities of a variety could occur through successive seed increases even though all plants produce seed stalks. This would seem to be a reasonable result of natural selection in varieties highly resistant to bolting.

To test the amount of deterioration in the non-bolting characteristics of sugar beets a field test was designed to include successive generations of two varieties. Four successive seed generations without selection were available from the varieties U. S. 56/2 and U. S. 75. Each increase of both varieties was produced in Oregon. U. S. 56/2 originated as SL659, and successive increases were numbered SL759, SL859 and U. S. 56/2, respectively. U. S. 75 originated as C975 and successive increases were numbered C075, C175 and U. S. 75, respectively. Table 1 shows the succession of increase of each variety, the parentage, and the year in which each increase was made.

Table 1.—Showing Parentage and Year of Seed Production of Four Successive Seed Generations in the Two Varieties, U. S. 56/ and U. S. 75.

Variety	Increased from	Year
SL659	—— [1]	1946
SL759	SL659	1947
SL859	SL759	1948
U. S. 56/2	SL859	1952
C975	—— [1]	1949
C075	C975	1950
C175	C075	1951
U. S. 75	C175	1952

[1] Original selections.

The field test consisted of eight replications arranged in a randomized complete block design. Plot size was two rows fifty feet long for each variety in each replication. The entire plot was harvested for yield determination. Counts were made during the growing season of number of beets per plot after thinning, number of beets bolting and number of beets infected with downy mildew caused by *Peronospora schachtii*. A beet was considered as a bolter if seed stalk initiation was visible whether or not seed was produced. A beet was considered to be infected with downy mildew if mycelia of *Peronospora schachtii* could be detected on the leaves. The plots were planted December 16, 1952, and harvested October 29, 1953.

Table 2 shows the average percentage of bolters, yield in tons per acre and percentages of plants infected with downy mildew. The bolting percentage of each successive reproduction of U. S. 56 can be seen to show a progressive increase. SL659, the original U. S. 56/2, showed 6.1 percent bolters, while U. S. 56/2 three seed increase generations later showed 14.4 with intermediate amounts in SL759 and SL859. With an L.S.D. at the five

percent level of 3.3 and at the one percent level of 4.4, the differences shown are highly significant. This would seem to indicate that natural selection was effective during the seed increases in reducing the high degree of bolting resistance possessed by the original variety.

Table 2.—Averages of Percentages of Bolted Beets, Yields and Percentages of Mildew Infection in Successive Seed Generations of Two Relatively Non-Bolting Varieties of Sugar Beets, U. S. 56/2 and U. S. 75. (Eight replications)

Variety	Percent Bolters	Yield Tons/Acre	Percent Mildew Infection
SL659	6.1	21.79	27.5
SL759	8.3	22.68	25.6
SL859	9.6	21.59	28.0
U. S. 56/2	14.4	21.90	26.9
C975	16.2	23.60	20.1
C075	10.1	24.75	18.1
C175	12.5	22.62	17.5
U. S. 75	13.3	22.05	18.9
L.S.D. 19:1	3.3	NS	6.6
L.S.D. 99:1	4.4	NS	8.8

The trend is not so consistent in the successive generations of U. .S 75. The reduction in bolting between C975 and C075 is difficult to explain because it would seem all factors of natural selection pressure would tend to increase the amount of bolting rather than to decrease it. While an error someplace in making up such a test is possible, a careful recheck of seed and method used has not located any mistake. Except for the first seed increase the pattern is similar in the U. S. 75 series to that for U. S. 56/2 in that a slight increase in bolting percentage is shown in each seed increase from C075 to U. S. 75. The difference in bolting percentage between C075 and U. S. 75 approaches but does not reach statistical significance at the five percent level. Because only the one seed increase showed a reduction in bolting and all other seed increases in both varieties showed an increase in bolting percentage with each successive generation, it is believed that it is correct to assume there is, in general, a deterioration in the bolting resistance of highly non-bolting varieties in successive generations of seed increase.

Table 2 indicates no significant differences between the yields of any of these varieties. Usually the yields are closely associated with bolting percentage in tests which are planted early enough for bolting to occur to any great exetnt. As was pointed out previously in making the counts of bolted beets in this study, any plant showing evidence of seed stalk elongation was considered to be a bolter whether or not seed was produced. Many of the beets counted as bolters had very short vegetative seed stalks which were not long enough to be seen above the foliage. Thus, it is possible that bolting had not progressed far enough to be a factor in reducing yields.

The mildew percentages as shown in Table 2 indicate a rather wide difference between the two series of varieties, but essentially no differences exist between succeeding generations within either the U. S. 56/2 or the U. S. 75 series. This was expected because there is no reason to believe that mildew resistance or succeptibility should be affected by natural selection

in a seed field in an area not subject to infection by downy mildew. Any exception to this may be due to close genetic linkage between factors conditioning resistance to mildew and those conditioning resistance to bolting.

Often, when a variety is first developed, only a small amount of seed is produced. Most of this seed may be used for preliminary evaluation tests to determine whether the strain is satisfactory for introduction as a commercial variety. Sometimes a seed increase of the original selection must be made before sufficient tests have been conducted to determine the value of the new strain. When a new strain is considered of enough value to become a commercial variety it is usually necessary to produce at least two seed generations to increase the seed to desired amounts.

Thus, three or four seed increases are almost always used in the transition from an experimental strain to its release as a commercial variety. These early increases are usually used as "stock" seed. Stock seed is the seed from which the commercial seed crop is grown and stock seed increases are made only as the supply becomes depleted. Periodically, however, further increases of stock seed are necessary to provide adequate supplies of seed for commercial increases, if a variety remains in demand for a long time.

The results of this study would indicate that any way of reducing the number of seed increases of a particular non-bolting variety would help maintain the non-bolting quality of the variety. Once a non-bolting strain is found desirable enough to be increased as a commercial variety probably larger stock seed increases should be made in an effort to reduce the number of increases required. Roguing of the early bolters from stock seed fields may help to maintain the non-bolting quality of a variety but no comparative data are available on the value of such a proceedure. If a satisfactory method of steckling reproduction could be developed for extremely non-bolting varieties, considerably larger seed increases could be produced from a given amount of seed than by direct seeding. This would reduce the number of seed increases necessary to provide the desired amount of seed.

When commercial varieties are hybrids whose component inbred lines are homozygous, this problem of deterioration in bolting resistance should be eliminated. In inbred lines, the difference in rate of bolting between different plants in a field would be due primarily to environmental differences, and because of lack of genetic variability within inbred lines, any major shift in a genetic characteristic between successive generations would indeed be unlikely.

Summary and Conclusions

A test was conducted to determine the effects on the non-bolting characteristics of successive seed generations in Oregon on two relatively non-bolting sugar beet varieties, U. S. 56/2 and U. S. 75. Most of the evidence indicated a deterioration in the non-bolting quality of the varieties. Yields and percentages of plants infected by downy mildew caused by *Peronospora schachtii* were not influenced in successive generations. The non-bolting quality of a variety is a characteristic which would lend itself much more to natural selection than would either root yield or percentage of mildew infection.

At least three or four seed increases are required from development to commercial utilization of a variety. Suggestions to reduce either the number of seed increases required or the effect of natural selection on each increase included:

1. Making larger stock seed increases, necessitating fewer of them; 2. a satisfactory method of steckling increases for stock seed in non-bolting varieties, because of the gain in amount of seed produced per pound seeded over the direct seeding method; 3. roguing early bolting plants in the seed field to eliminate them from seed production, and 4. the use of hybrid varieties whose component inbreds are homogygous for the non-bolting characteristics.

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A Rapid Method of Making a Non-Bolting Selection in Sugar Beets

RUSSELL T. JOHNSON[1]

The development of seed stalks in sugar beets has been termed "bolting." Bolting is necessary for reproduction in a seed field, but is highly undesirable in a commercial sugar beet field. Conditions conducive to induce bolting in sugar beets are low temperatures followed by periods of long days. Artificial or natural conditions may be used to supply either or both of these requirements. While bolting is largely dependent upon environmental conditions, it is also influenced by heredity. Differences between varieties exist in the amounts of thermal induction required for them to bolt. In the field this appears as different percentages of bolters with different varieties in plantings made early enough that bolting occurs.

In some sections of California there are some advantages in planting sugar beets as early as December or even earlier. Beets planted then receive considerable thermal induction during the remainder of the winter and, with the increased temperatures and day length of spring, many of them bolt during the growing season. If excessive bolting occurs in a commercial field of beets, the disadvantages are threefold: a loss in root yield (1)[2], fouling the ground with beet seed and difficulty in harvesting.

While the inheritance of bolting tendencies is not well understood, selection has been effective in developing varieties which resist, to a considerable extent, the conditions which induce bolting. Such varieties are referred to as non-bolting varieties. An example of effective selection for non-bolting might be cited in the improvement made in the highly curly-top-resistant, easy bolting variety U. S. 22/3. Dr. Leroy Powers, formerly of Spreckels Sugar Company, made a non-bolting selection in U. S. 22/3 which produced the Spreckels variety, S-2. From this variety, Dr. J. S. McFarlane (3) of U.S.D.A. made a further selection resulting in the variety U. S. 75. S-2 and U. S. 75, respectively, show a progressive improvement in the non-bolting characteristic over the variety U. S. 22/3.

The normal method of making a non-bolting selection in California is to plant seed of a variety in the fall, overwinter the beets in the ground, and select the otherwise desirable beets that do not bolt the following summer. These selected roots are lifted and reset in an isolation plot or refrigerated for a time and then reset into an isolation plot. In such a plot seed is produced on surviving roots that bolt the next summer. Such a selection requires essentially two years' time from seed to seed. Any method which would reduce this time would speed the process of utilizing improved non-bolting characteristics in commercial varieties.

Efforts have been reported on methods of speeding the time required for seed production by use of artificial light or refrigeration or combinations of both (2), but information is lacking on the effectiveness of non-bolting selections under such conditions.

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[1] Plant Breeder, Spreckles Sugar Company, Spreckles, California.
[2] Numbers in parentheses refer to literature cited.

In November of 1951 a selection for ability to germinate at cold temperatures was made in a strain of beets numbered A5116. This is a variety high in curly top resistance and medium in bolting resistance. Germinating seedlings after twelve days at 38°-40° F. were placed between moist blotters for 24 to 36 hours at 70° F. to facilitate selection of only the most rapid germinating seedlings from each seedball. Selected seedlings were then transplanted into 14 x 20 x 3-inch flats of sterilized soil, about 175 plants per flat, and covered with ¼ inch of sand. These flats were then kept in the warm greenhouse (60°-65° F.) for seven days to give seedlings a good start. At this time the flats were moved to tables in an unheated greenhouse under continuous light. These flats were rotated on the tables one position twice a week to minimize any effect of differential light intensity.

Artificial light was supplied from dark until daylight by means of one 100-watt bulb in a reflector placed 42 inches above each table. Minimum greenhouse temperatures during this period ranged from 30° to 40° F. and maximum temperatures ranged from 50° to 65° F. By February 15 some small seed stalks were beginning to appear. With 175 plants in a flat, satisfactory later transplanting to isolation plots could not be accomplished, so, to reduce the number of plants in the flats, the early bolters were removed as they appeared. Approximately 80 percent of the plants were removed in this manner.

By April 1 most of the remaining plants were producing seed stalks. Only six plants did not show evidence of producing a seed stalk. The bolting plants were set out in isolation and produced seed harvested in August of 1952 and numbered A5211. Approximately six hundred plants were involved in this increase.

The six plants which did not produce seed stalks were refrigerated for an additional month and later allowed to flower and interpollinate among themselves in the greenhouse. Seed produced from these six plants was harvested in October, 1952, and numbered A5240.

If a selection for non-bolting by the removal of the fast bolters under these conditions was effective, A5211 and A5240, respectively, should show a progressive improvement over the non-bolting tendency of the parent, A5116.

To test this theory a field experiment was designed which included the three varieties, A5116, A5211 and A5340, together with the non-bolting varieties U. S. 56/2 and U. S. 75 as checks. This test consisted of eight replications of two-row, forty-foot plots of each variety arranged in a randomized complete block design. Number of plants per plot and number of beets bolting were counted and the entire plots were harvested for yield determination. A beet was considered to be a bolter if seed stalk development had been initiated, whether or not seed was produced on it. Counts of plants infected with downy mildew caused by *Peronospora schachtii* were also made and recorded. The test was planted to moisture on December 16, 1952, and harvested October 29, 1953. Mid-December was selected as a planting date, as being early enough that some bolting would occur but not early enough to approach complete bolting.

Table 1.—Showing Average Percentages of Bolted Beets, Yields in tons per Acre and Mildew Infection Percentages from a Field Test of Three Experimental Strains and Two Commercial Check Varieties of Sugar Beet s(eight replications).

Variety	%[1] Bolters	Yield Tons/Acre	% Mildew[1] Infection
A5116	18.1	24.33	13.5
A5211	10.7	25.38	13.7
A5240	6.6	21.17	13.0
U. S. 75 (C175)	11.4	22.73	18.8
U. S. 56/2	14.2	20.69	27.0
L.S.D. at P = .05	3.9	2.56	6.4
L.S.D. at P = .01	5.4	3.45	8.4

[1] Analyses of variance on bolting and mildew percentages computed after converting original data to $\sin^2 \theta$.

Table 1 shows a summary of the results of bolting percentages, mildew percentages and yields of the three experimental varieties together with the check varieties, U. S. 56/2 and U. S. 75. It is interesting to note that A5211 is significantly lower in bolting percentage than A5116, and A5240 is significantly lower than A5211. This progressive improvement in the non-bolting characteristics of A5116 indicates conclusively that selection had been effective under these conditions. A comparison of the selections with the check indicates that A5211 is about in the same class as U. S. 56/2 and U. S. 75 in its non-bolting tendency and A5240 is significantly better than either of them. Both U. S. 56/2 and U. S. 75 represent as high a degree of non-bolting as is presently available in commercial varieties, so it appears that this selection was effective even in what is considered at present to be very non-bolting material.

The yield of A5240 was significantly lower than A5211 or A5116. It is believed that this was due to the limited parentage comprising the strain. As was mentioned above, only six plants which were extremely slow to develop seed stalks were interpollinated to produce it. Certainly a reduced yield is not characteristic of this type of selection, because A5211 shows no reduction over A5116.

In percentage of infection of downy mildew there is no difference in susceptibility between any two of the three strains involved in the selection. This was as expected because downy mildew was in no way a factor in the selection.

These selections were made, as pointed out above, in material which had been selected for its ability to germinate at low temperatures. Resistance to bolting and ability to germinate and grow at low temperatures is a desirable combination of characteristics for a variety to be planted early in California when temperatures are low.

The importance of this method of selection is twofold; it makes possible more rapid commercial utilization of new non-bolting strains by cutting selection time in half, and makes possible a more rapid elimination of undesirable material in any new breeding program in which non-bolting is a desired characteristic.

Some slight modifications have been made in this method since its initiation. Seedlings, when first selected for germination at cold temperatures, are transplanted directly into flats covered with ¼ inch of sand and allowed to grow in a heated greenhouse (60°-65° F.) for four days. Any seedling emerging after that time is destroyed because of the possibility of its being from a locule in the seedball other than the one from which the first seedling emerged. This eliminates the extra step of moving them from the cold germinating chambers to blotters at warm temperatures before transplanting them in flats. This particular problem is eliminated by the use of single germ seed. Because each seed contains only one locule, transplanting from cold germination directly into flats can be made without danger of slower germinating seedlings from other locules emerging after transplanting.

Summary and Conclusions

A method of making a non-bolting selection in sugar beets is described which requires less than a year from seed to seed even in relatively non-bolting material. The method described was used to produce a variety equal in bolting resistance to U. S. 56/2 and U. S. 75 and showed possibilities that it might be used to produce varieties possessing even greater bolting resistance. Characteristics other than bolting resistance were apparently not affected by the selection.

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New Non-Bolting and Mildew-Resistant Seed Releases

J. S. McFarlane[1]

The sugar beet breeder who is developing hybrid varieties for use in California has need for breeding stocks which combine bolting resistance with curly top resistance. For use in the coastal districts it is desirable that they be resistant to downy mildew and rust. It is also advantageous to incorporate the type O character, which insures that all the offspring from crosses to cytoplasmic male steriles will be completely male sterile. Three breeding stocks which possess certain of these characters have been made available to the breeders through the Beet Sugar Development Foundation. The pedigrees and brief descriptions of these stocks are given in this paper.

NB 1 and Its Male Sterile Equivalent

NB 1 — S_5 (Cl 179 x Cl 1-707)

Cl 179 — Type O clone with high sucrose percentage from U. S. 1

Cl 1-707 — Self fertile inbred high in curly top resistance and dark green in color

The cross, Cl 179 x Cl 1-707, and the early inbred selections from it were made at Salt Lake City, Utah, by Dr. F. V. Owen. A composite of S_4 lines which had arisen from a selected S_2 line was planted at Salinas, California, in the fall of 1948. Non-bolting plants were selected the following summer based on vigor, root characteristics, and freedom from yellowing. S_5 seed was obtained from these selected beets in 1950 and tests made with the selfed progenies in 1951. NB 1 is an increase of the S_5 line which showed the greatest promise.

The inbred, NB 1, has been thoroughly tested in California, in Oregon seed plots, in Idaho curly top tests, and in the 1952 sugar beet breeders' cooperative inbred tests. Results of these tests show that it is resistant to bolting, is superior to U. S. 22/3 in curly top resistance, possesses average downy mildew and rust resistance, has average root size, is a little below average in percent sucrose, is low in sodium content, and is a good seed producer.

Difficulty with bolting in the seed plots has been experienced both at Medford and Salem, Oregon, unless the plantings are made by August 1. The inbred has been found to germinate poorly at temperatures below 45° F. In a test conducted in 1952 at Shelley, Idaho, by the Utah-Idaho Sugar Company the NB 1 inbred was found to be highly resistant to the black bean aphid, *Aphis fabae* (Scop.). Tests at both Salinas, California, and Salem, Oregon, showed NB 1 to be relatively free from the yellowing associated with virus yellows when most other surrounding inbreds were severely yellowed. The inbred has proved to be highly self fertile and an excellent type O.

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Hybrids produced for the purpose of measuring the combining ability of NB 1 have failed to yield significantly higher than the male parent, but most of these hybrids have shown a higher sucrose percentage than has the male parent.

The male sterile equivalent of NB 1 has also been released through the Beet Sugar Development Foundation. This MS equivalent represents the fourth backcross to NB 1 or to earlier generations of this inbred. It has shown a little less bolting resistance than NB 1. The source of male sterile cytoplasm used in producing this MS equivalent was a male sterile U. S. 56 clone discovered by Dr. F. V. Owen.

C361 and Its Male Sterile Equivalent

C361 = Type O, non-bolting selection from U. S. 22/3

In 1950, a group of 110 plants of a non-bolting selection from U. S. 22/3 were indexed for male sterility of which six were classed as approaching type O in their genetic constitution. Seed was produced from these six clones in an isolated plot. A group of 100 plants from this selection was again indexed of which 15 were classed as type O. A seed increase from these 15 plants was planted at Salinas in August, 1952. A bolting selection was made during 1953 by eliminating three-fourths of the plants which were the fastest bolters. Seed from the slower bolting plants has been designated C361.

During the development of C361, a male sterile equivalent has also been produced. The source of the cytoplasmic male sterility is the same U. S. 56 clone as for the MS of NB 1. Four backcrosses to C361-type plants have been made. Tests with the male sterile equivalent have shown that it is free of pollen producers. However, under some growing conditions a portion of the plants may produce yellow colored anthers.

C3504—Mildew Resistant Inbred

C3504 = Composite of three S_5 lines from the hybrid SL 51-1 x 4200-14

SL 51-1 = Clone from U. S. 22/3

4200-14 = Non-bolting inbred similar to NB 1

In 1948 a greenhouse mildew selection was made from an F_2 population of the hybrid SL 51-1 x 4200-14. The inbred progenies of the selected plants were tested for mildew resistance in the field and an increase was made of the most resistant S_3 line. Another greenhouse mildew selection was made from this increase in 1951, and 30 selected S_4 lines were tested in the field in 1953. S_5 seed from three of the most promising lines was composited and designated C3504.

Tests made in 1953 with C3504 show that it possesses high field resistance to downy mildew. Localized leaf infections were observed on a small percentage of the young plants but they recovered without permanent damage. The inbred showed moderate resistance to bolting and to rust. Tests with the S_3 line from which C3504 was selected showed good resistance to curly top. Combining ability tests have not been made.

Testing Sugar Beet Varieties for Their Resistance to Aphanomyces, Rhizoctonia and Fusarium Root Rots[1]

M. M. Afanasiev and H. E. Morris[2]

The relation of various varieties of sugar beets to several soil-bourne diseases of beets was studied in this investigation, which is a part of an overall project involving the study of many qualities of different varieties of sugar beets.

This work is headed by the Sugar Beet Breeders Forum, composed of research workers of various sugar companies and those employed by different government and state institutions and agencies.

During the period of 1950-1953, 240 different varieties of sugar beets obtained from various sources and some raised in Montana were tested for their resistance to the three following diseases:

1. Aphanomyces root rot, caused by *Aphanomyces cochlioides* Drechs.
2. Rhizoctonia root rot, caused by *Rhizoctonia solani* (*Pellicularia filamentosa* (Pat.) (Rogers).
3. Fusarium root rot (yellows), caused by *Fusarium oxysporum* f. *betae* (D. Stewart) Snyder and Hansen.

Twenty-four of these varieties were supplied by the Great Western Sugar Company, Longmont, Colorado; 48 by the Holly Sugar Corporation, Sheridan, Wyoming; 53 by the U. S. Sugar Plant Field Laboratory, Salt Lake City, Utah; 76 by G. W. Deming, U.S.D.A., Fort Collins, Colorado; 15 by H. L. Kohls, Michigan State College, East Lansing, Michigan; 1 by the American Crystal Sugar Company, Rocky Ford, Colorado; and 1 by J. S. McFarlan, U.S.D.A., Salinas, California, while 22 were raised in Montana.

Tests were conducted under field and greenhouse conditions if a sufficient amount of seed was available; otherwise only greenhouse tests were made. Only limited field tests were conducted during 1950. Intensive greenhouse and field work was started in 1951.

Field work was conducted at the Huntley Branch Station, Huntley, Montana, in heavily infested soil. Usually several replications of each variety were planted. Stand counts and disease readings were made in these plots several times during the growing season. At harvest beets were dug and detailed readings were taken on the occurrence of disease. Under field conditions beets were tested only for their resistance to rhizoctonia and fusarium root rots.

Greenhouse tests were conducted at Bozeman, Montana, in soils brought from the Huntley Station. At first, attempts were made to conduct these tests in soil flats sterilized with chloropicrin and inoculated with the respective organisms. This method was discontinued because of the incon-

[1] Contribution from Montana State College, Agricultural Experiment Station, Bozeman, Montana. Paper No. 323, Journal Series.

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venience of using chloropicrin in the greenhouse where other plants were growing.

Later an attempt was made to test these varieties in nonsterilized soil in greenhouse benches. Before planting beets the soil was inoculated with the specific organism, and in addition beets infected with the respective organism were finely chopped and mixed into the specific soil. Although results were good with this method, still there were a few objections to it. Each tested soil was predominantly infested with a specific organism, but other pathogenic organisms were also present in it, and it was difficult to differentiate on the basis of symptoms the causal factor of the disease. It was also found that pathogenicity of the organisms gradually decreased in nonsterilized soil. It appears that certain conditions occurred in the nonsterilized inoculated soil which led to a decrease in number or virulence of the pathogenic organisms.

All these considerations led to the conclusion that, in further tests, sterilized inoculated soil should be used. This proved a more satisfactory standard testing technic and allowed a better comparison between individual tests.

The following standard procedure was adapted in all greenhouse tests:

Each variety of beets was tested for each disease in three 7-inch pots filled with Huntley soil. Prior to each planting, pots filled with soil, and saucers, were steam sterilized for four hours at 15 pounds pressure in the autoclave. Using this method, each of the pots can be considered as a separate replication. Usually 20 whole sugar beet seeds were planted in each pot.

It was also found that disinfection of seeds with New Improved Ceresan will eliminate possible seed-borne infection; for example, one which is caused by *Phoma betae*. Disinfection of seed was usually done about one month prior to planting. After emergence beets were allowed to grow for about 5-6 weeks and then they were harvested. Regular readings of healthy and diseased beets were taken during the growing period and also at harvest. Inoculum used in the soil was composed of several cultures of the pathogenic organisms, whose pathogenicity was previously tested. During the 1951-53 period four cultures of *Aphanomyces cochlioides*, six cultures of *Rhizoctonia solani* and three cultures of *Fusarium oxysporum* f. *betae* were used as inoculum.

In comparing the results of field and greenhouse tests, it appears that the greenhouse tests were more uniform and reliable. There are too many factors in field testing which make it impossible to control the disease factor. One year rhizoctonia root rot may be the predominant disease in a certain field, but the next year there may be another pathogen which makes an inroad in this field.

The plan is to submit all available varieties of beets to the greenhouse test. Field tests will be used to supplement the greenhouse tests. Later those varieties which showed the best possibilities will be rechecked under greenhouse conditions. Selection of individual beets from the varieties showing the highest degree of resistance will be made. These beets will be used for seed production and the progeny will be tested.

No attempt will be made to give the relative degree of resistance to the root rots of each of the tested varieties in this report. Only those varieties will be mentioned which showed a comparatively high degree of resistance to these diseases.

Those varieties of beets which showed the highest degree of resistance to the diseases among 240 varieties of beets tested under greenhouse conditions are listed in Table 1. All those beet varieties which are reported in this table as being used in three replications (3 pots), including Deming 1952-333, were tested in sterilized soil. The remaining varieties were tested in nonsterilized, inoculated soil in benches when only two replications were used.

Table 1.—Percent of Healthy Sugar Beet Seedlings in Tests of Beet Varieties for Their Resistance to Aphanomyces, Rhizoctonia, and Fusarium Root Rots. Greenhouse, 1951-52, Bozeman, Montana.

Varieties Tested	Replications 1	2	3	Varieties Tested	Replications 1	2	3	Varieties Tested	Replications 1	2	3
Aphanomyces Root Rot											
H[2] 1123-0	25	12	7	D 1950-351	73	71	—	D 1951-517	18	17	10
SL 1-504-2	6	7	15	D 1950-540	91	73	—				
Rhizoctonia Root Rot											
GW 359	71	55	56	D 1950-387	59	53	—	D 1950-479	65	67	—
GW I-3	68	70	58	D 1950-392	59	77	—	D 1950-480	64	75	—
GW I-5	60	54	67	D 1950-393	56	80	—	D 1950-540	86	77	—
H 0117-0	55	53	—	D 1950-406	80	82	—	D 1950-581	81	60	—
H 1119-0	61	52	—	D 1950-413	78	62	—	D 1950-623	79	53	—
H M W 391	77	69	74	D 1950-415	85	68	—	D 1951-500	100	100	86
SL 1019	71	70	—	D 1950-422	77	64	—	D 1951-622	68	80	100
SL 9092	77	70	58	D 1950-444	74	63	—	K 310; 851702	57	59	53
D 1950-351	94	71	—	D 1950-464	66	60	—	K 310; 851909	68	89	66
D 1950-357	55	54	—	D 1950-466	62	94	—	K 328; 234901-10	69	62	50
D 1950-361	71	54	—	D 1950-467	82	74	—	M-11	54	60	—
D 1950-370	55	71	—	D 1950-471	69	73	—	Am Cr 9-406-0	80	80	67
D 1950-385	89	57	—								
Fusarium Root Rot											
GW 359	92	88	89	D 1951-370	57	61	79	D 1952-350	91	92	94
GW I-2	92	100	95	D 1951-391	85	82	77	D 1952-359	85	100	80
GW I-3	80	85	93	D 1951-399	94	100	78	D 1952-369	73	58	89
GW I-4	79	74	66	D 1951-402	95	100	100	K 32; 57302	75	85	100
GW I-5	100	96	94	D 1951-412	55	52	80	K 32; 57305	56	55	63
H 0122-0	79	94	78	D 1951-448	60	88	82	K [1]35; 410603	100	94	77
H 1120-0	84	73	100	D 1951-480	89	84	89	K 35; 410701	96	100	85
H 1123-0	100	100	100	D 1951-500	83	100	100	K 297; 624710	64	57	60
H 1124-0	84	73	77	D 1951-623	86	91	91	K 310; 851702	75	60	79
H 51-51	89	100	98	D 1952[1]-305	59	79	86	K 310; 851909	98	94	73
H MW 391	94	100	98	D 1952-307	95	90	93	K 321; BL01-02	85	96	73
H US 22/3	71	86	85	D 1952-324	96	85	73	K 328; 234301-41	79	93	68
SL 509	92	100	100	D 1952-333	67	—	75	K 328; 234801-30	72	79	77
D 1950-558	72	72	—	D 1952-334	77	83	82	K 328; 234901-10	54	80	63
D 1951-319	60	73	85	D 1952-336	93	89	84	K 346; 219901	93	95	82
D 1951-335	70	66	82	D 1952-340	74	67	93	[1]Am Cr 9-406-0	78	96	77
D 1951-338	83	84	86	D 1952-347	67	77	77	McF S C 0502	53	52	94
D 1951-356	73	61	52	D 1952-349	95	100	93				

[1] Deming 1952, Kohls Accession 35 and higher, and American Crystal 9-406-0 need additional testing, as degree of pathogenicity was low during this test.

[2] H-Holly Sugar Corporation; GW-Great Western Sugar Company; Am Cr-American Crystal Sugar Company; SL-Salt Lake USDA; D-Deming USDA; McF-McFarlan USDA; K-Kohls, Michigan; M-Montana.

Five varieties of beets showed the highest degree of resistance to aphanomyces root rot, 37 varieties to rhizoctonia root rot and 53 varieties to fusarium root rot (Table 1). Only those varieties of beets which had in all replications more than 50 percent of healthy beets are included (Table 1). There was only one exception to this rule, which is given in the Aphanomyces test. Three varieties of beets are included which, although they showed a lower percentage of healthy beets, had healthy beets present in all three replications. The degree of pathogenicity of aphanomyces cultures was very high and often 100 percent infection occurred in all replications. For this reason the three varieties showing the highest degree of resistance when beets were tested in sterilized soil are included in this list.

The degree of pathogenicity of rhizoctonia cultures was also high throughout the duration of all tests. Fusarium cultures for the most part showed a high degree of pathogenicity with the exception of the tests conducted during the fall and winter of 1953 when the degree of pathogenicity was low. Twenty-three varieties of beets of this last group reported in Table 1 will again be tested for fusarium root rot. Not a single variety of beets showed a high degree of resistance to all three diseases (Table 1). However, a number of varieties showed a high degree of resistance to two out of three types of root rots.

Only 12 varieties of beets, reported in Table 1, for greenhouse tests were used in the field test. These varieties and their relative resistance to rhizoctonia and fusarium root rots under field conditions are summarized in Table 2. All varieties showed a high degree of resistance to both rhizoctonia and fusarium root rots with the exception of SL9092, which was low in resistance toward fusarium.

Table 2.—Percent of Healthy Sugar Beets in Tests of Beet Varieties for Their Resistance to Rhizoctonia and Fusarium Root Rots Under Field Conditions. Huntley Branch Station, Huntley, Montana. 1951-52.

	Root Rots				Root Rots		
	1951	1952			1951	1952	
Varieties Tested	Rhizoctonia	Rhizoctonia	Fusarium	Varieties Tested	Rhizoctonia	Rhizoctonia	Fusarium
G.W. 359	87	73	77	Holly 1124-0	—	76	80
Holly 0117-0	—	82	73	Holly 51-51	—	72	75
Holly 0122-0	—	75	87	Holly MW-391	—	66	77
Holly 1119-0	—	83	88	SL 509	—	57	91
Holly 1120-0	—	76	82	SL 1019	—	69	70
Holly 1123-0	—	70	92	SL 9092	—	78	0

Summary

In the present investigation, resistance to 240 varieties of beets was studied under greenhouse conditions in regard to aphanomyces, rhizoctonia and fusarium root rot diseases. Among these varieties of beets, five varieties showed the highest degree of resistance to aphanomyces root rot, 37 varieties to rhizoctonia root rot and 53 varieties to fusarium root rot. Additional tests will be conducted to further evaluate the resistance of these varieties of beets to those root rots.

A Summary of Results in the Breeding for Resistance to Aphanomyces Cochlioides (Drecks) by the American Crystal Sugar Company Since 1942

C. W. Doxtator and R. E. Finkner[1]

Root rot of sugar beets caused by *Aphanomyces cochlioides* (Drecks) has been prevalent in the Minnesota and Iowa sugar beet growing areas of the United States for many years (4)[2]. Laggard plant growth, caused by the persistant attack of the pathogen on the seedling and the small feeder roots, and also the rot of the main root which may result in the death of the plant, are the chief manifestations of the disease. The work of various investigators of this root rot disease was summarized by Coons et al (3) in 1946.

Observations that varieties and selections of sugar beets differed in their resistance to rotting by *Aphanomyces cochlioides* led to the development of a program some 12 years ago of breeding for resistance to this organism by both the American Crystal Sugar Company and the United States Department of Agriculture. Reports on progress for resistance to this root rot have been made by a number of workers, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11. Bockstahler et al (2) studied different crosses using resistant and susceptible parents and concluded that resistance to *Aphanomyces cochlioides* was Mendelian and dominant; and similar results were obtained by the research personnel of the American Crystal Sugar Company.

Procedure and Results

The selection of beets which were resistant to *Aphanomyces cochlioides* was started by the American Crystal Sugar Company in 1942 and was continued up to the present date. Very slow progress was made in the first years but recent selections have been extremely promising. Mass selection with modifications has been the main method of breeding.

A sixteen-strain test in three replications of plots were grown on soil naturally infested with *Aphanomyces cochlioides* at Mason City, Iowa, during the years 1952 and 1953. Eleven of the strains tested in 1952 also were tested in 1953. The results of these two tests are presented in Tables 1 and 2.

When comparisons were made of the yields of the varieties common in both years tested, it appears that the epiphytotic of the disease and/or the pathenogenicity of the organism was not as servere in 1953 as in 1952. However, strain 5-419, the first root rot-resistant selection produced by the Company, gave approximately the same yield in both years. Strain 1-602, selected in 1950, ranked the highest in 1952 both in tonnage yield and in pounds sugar per acre; and was excelled in 1953 only by the 1951 selection 2-703.

Strain 2-703 was a seed increase from 23 roots selected at Waseca, Minnesota, from breeding material tested under severe root rot conditions. The third ranking strain was obtained from root rot-resistant plants grown

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[1] Manager of Agricultural Research, and Plant Breeder respectively, at Rocky Ford, Colorado.

[2] Numbers in parentheses refer to literature cited.

for seed production in the greenhouses at Rocky Ford, Colorado, during the winter of 1952-53. The seed from outstanding plants was bulked together and labeled as RF GH No. 5.

Five new selections were added to the 1953 strain test. All of the selections, except the commercial American No. 3 S which was included as a second check, were breeders' stocks selected under root rot conditions. The new selections ranked high in yield with the lowest (0-804) holding seventh position.

Table 1.—Mason City Root Rot Strain Test—1952.

Variety	Year of Selection	Tons Beets per Acre	Percent Sucrose	Lbs. Sugar per Acre	% Na	% K
1-602	1950	10.53	14.05	2,985	.029	.148
1-604[1]	1950	9.68	14.33	2,773	.041	.149
1-607	1950	9.26	14.38	2,648	.032	.151
7-609-X	1946	9.40	14.05	2,634	.040	.137
1-703	1950	9.03	14.45	2,605	.027	.124
1-4060	1949	9.07	13.72	2,495	.033	.154
0-602	1949	8.22	14.57	2,402	.034	.140
1-4062	1950	7.99	14.45	2,305	.038	.148
9-406-0	1947	9.46	14.33	2,249	.033	.146
1-802	1950	7.71	14.23	2,188	.031	.147
9-801	1950	6.68	13.42	1,790	.041	.166
Am No. 3 LSR	check	5.80	14.72	1,706	.033	.146
1-4061	1949	6.34	12.98	1,645	.052	.157
6-423-X	1945	5.88	13.48	1,572	.036	.151
1-4007[2]	1949	5.20	14.18	1,472	.031	.161
5-419	1944	5.31	13.83	1,452	.039	.143
General Mean		7.85	14.07	2,183	.036	.148
Sig. Diff. (19:1)		2.42	.84	732	.011	NS[3]

[1] A selection of U.S.D.A.—48-B3-00.
[2] Selected for rhizoctonia resistance.
[3] Not significant.

Table 2.—Mason City Root Rot Strain Test—1953.

Variety	Year of Selection	Tons Beets per Acre	Percent Sucrose	Lbs. Sugar per Acre	% Na	% Ca	% Raff
2-703	1951	15.66	16.93	5,299	.035	.007	.118
1-602	1950	14.55	17.78	5,141	.023	.007	.167
RF GH No. 5	1951	13.50	17.42	4,703	.030	.007	.148
50-B3-0[1]		12.53	17.33	4,345	.038	.007	.175
1-607	1950	12.15	17.65	4,272	.022	.008	.200
1-703	1950	12.46	17.07	4,250	.045	.007	.165
0-804[2]	1949	12.28	17.25	4,229	.033	.006	.135
1-604[3]	1950	11.07	18.18	3,983	.032	.006	.192
9-406-0	1948	11.11	17.41	3,872	.026	.008	.125
Am No. 3 S	check	11.26	17.17	3,854	.034	.006	.150
0-603	1949	9.54	17.87	3,399	.028	.006	.142
Am No. 3 LSR	check	9.30	17.62	3,293	.026	.006	.125
1-802	1952	9.47	17.15	3,255	.030	.006	.120
9-801[4]	1948	8.33	17.73	2,962	.037	.006	.140
6-423-X	1945	7.58	16.97	2,557	.034	.007	.175
5-419	1944	4.79	17.03	1,656	.042	.008	.192
General Mean		10.97	17.41	3,817	.032	.007	.154
Sig. Diff. (19:1)		3.33	NS[5]	1,113	NS	NS	NS

[1] U. S. No. 400.
[2] First selection, Amer. No. 3N.
[3] Selection from U.S.D.A. 48-B3-00.
[4] First selection, Amer. 3LSR.
[5] N.S. = non significant.

Two selections of U.S.D.A. root rot-resistant varieties were entered in the 1953 test. Strain 1-604 was a reselection of the U.S.D.A. number 48-B3-00; and 50-B3-0 was recently released by the United States Department of Agriculture as U. S. 400. Selection 1-604 also was tested in 1952 and ranked second in yield of total pounds of sugar produced per acre. In the 1953 test, the two selections 1-604 and 50-B3-0 ranked eighth and fourth respectively, for sugar per acre yield.

It is evident from the data given in Tables 1 and 2, as well as from Figure 1, that in the past 10 years there has been a great advance in the breeding for resistance to *Aphanomyces cochlioides*. It is obvious that the recent selections are superior to the present commercial check varieties, as well as the earlier selections.

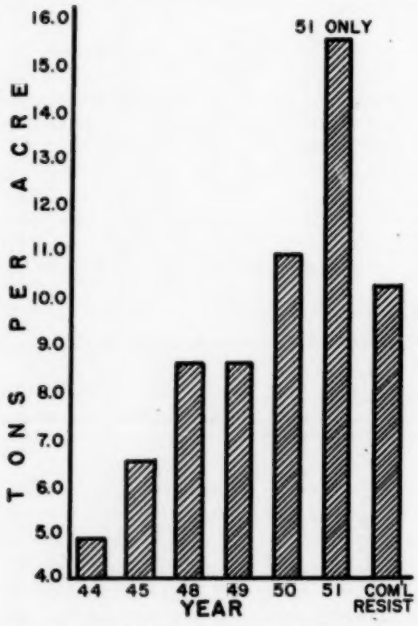

Figure 1.—The resistance obtained to Aphanomyces root rot, 1944-1952. A two year average (except the 1951 —one year average) of seven Aphanomyces root rot resistance strains and the increased resistance obtained during the past eleven years of breeding for resistance to Aphanomyces root rot.

The criterion used for determining resistance to Aphanomyces root rot has been pounds sugar produced per acre. This standard contains two important components; percent sucrose and tons of beets per acre. The tonnage component also contains two factors, yield genes and root rot-resistant genes. As of this date it has not been possible to separate the two. The correlations in Table 3 are of interest, but they offer no method for separating the above two factors.

Highly significant correlations were obtained between tons of beets per acre and pounds of sugar per acre in both years. This would be expected, as tonnage is the most important component in the amount of sugar produced per acre.

Table 3.—Correlation Coefficients of Seven Characteristics of Sixteen Varieties Tested Under Root Rot Conditions at Mason City, Iowa.

	Tons per Acre	Percent Sucrose	Lbs. Sucrose per Acre	% Na	% Ca
		1952			
Percent Sucrose	.325	.....	.....	.....	.....
Lbs. Sugar per Acre	.970[2]	.414	.....	.....	.....
% Na	—.288	—.644[2]	—.388	.....	.....
% K	—.377	—.526[1]	—.426	.374	.....
		1953			
Percent Sucrose	.062	.....	.....	.....	.....
Lbs. Sugar per Acre	.997[2]	.137	.....	.....	.....
% Na	—.257	—.522[1]	—.300	.....	.....
% Ca	.022	—.293	.085	.013	.....
% Raffinose	.191	—.202	.170	—.146	—.437

[1] 5% r = .497.
[2] 1% r = .623

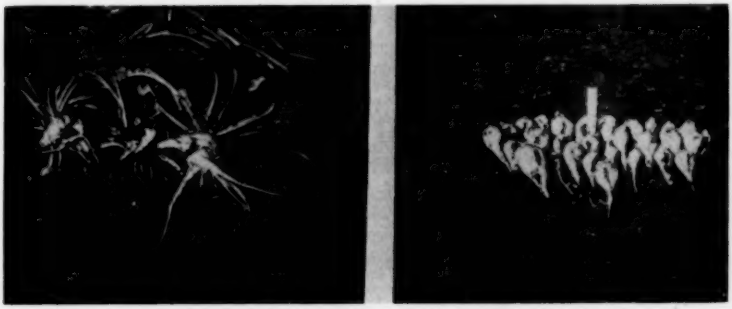

Figure 2.—Differences between two inbred lines which appeared resistant to root rot when looking at top growth.

Significant negative correlations were obtained between sodium and sucrose in 1952 and 1953, and in 1952 between sucrose and potassium, which is in agreement with the findings reported by Doxtator and Bauserman (9).

Along with the mass selection breeding program for root rot resistance many outstanding plants have been selfpollinated. The objective of inbreeding is twofold: A. to isolate desirable biotypes, and B. to change the gene frequency, since differences in inbred lines are due to the changes in gene frequency. One of the extremely promising inbred lines is shown in Figure 2, compared to a completely unsatisfactory selfed line. With the objective to obtain hybrids, increased emphasis is now being placed on inbreeding and the isolating of desirable biotypes.

Summary

Remarkable advances have been made since 1944 by the American Crystal Sugar Company as well as by the United States Department of Agriculture in obtaining beets resistant to the root rot caused by *Aphanomyces cochlioides.*

New selections are definitely more resistant than the first selected strains. Inbred lines which are highly resistant to *Aphanomyces cochlioides* are now being studied.

ACKNOWLEDGMENT

The improvement in root rot resistance obtained since 1952 could not have been achieved had it not been for the whole hearted cooperation of company research assistants, factory managers, agriculturists and many others.

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Beet Varietal and Species Reactions to the 1953 Curly Top Exposure at Jerome, Idaho

ALBERT M. MURPHY AND N. J. GIDDINGS[1]

Introduction

It is well known that the curly top disease caused almost complete abandonment of the sugar beet industry in several western states from 1916 to 1934. This disease still causes severe injury to tomatoes, some bean varieties, and a number of other crops. Curly top is characterized by sporadic and destructive outbreaks, but farmers can now plant resistant sugar beet varieties with confidence that the crop will yield reasonably well, despite some loss in the worst years. However, it cannot be said that curly top has vanished, nor has the curly top problem completely disappeared. Some lines of sugar beets possess outstanding characters and yet are susceptible to curly top, which restricts their utilization. Notable in this respect were the new monogerm races discovered by Dr. V. F. Savitsky in 1948.

The sugar beet breeding program has its complications. Not only is curly top sporadic so that natural conditions cannot be depended upon to give the desired exposure every year, but curly top is also made up of numerous strains which produce different symptoms and effects (4)[2]. Added to the difficulty with symptoms is the discovery by Bennett (1) concerning vein clearing which is usually one of the earliest curly top symptoms noted on young leaves of sugar beets. He has shown that certain non-viruliferous beet leafhoppers from stock cultures or field collections, when fed on seedling sugar beet plants, occasionally induce a vein clearing similar to that produced by curly-top virus but which is not curly top. Thus, many factors must be considered when evaluating new breeding material.

Methods

For the past sixteen years of breeding, the natural exposure to curly top in the experimental fields has been augmented to a certain extent by artificial means. A previous paper (5) reports some of the methods devised to bring about the desired curly top exposure for test purposes.

In 1953, crosswise strips of the susceptible Klein E variety from Germany (also known as R. and G. Old Type) were planted May 6. These strips were 15 feet wide and 100 feet apart (Figure 1). In addition to these crosswise strips, Klein E seed was also used for planting the buffers on each end of the field. These buffer strips varied in width from 15 to 50 feet. In every other row in these crosswise strips, a diseased beet from the previous season was transplanted. Beet leafhopper developed abundantly on the susceptible variety. Test material was planted June 15 and July 16 at right angles to the crosswise strips planted May 6. When beets from these plantings emerged the leafhoppers moved in on the small seedlings in great numbers from the crosswise-planted sugar beets. This brought about very severe curly top injury and a very high mortality.

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[1] Agronomist and Collaborator (formerly Senior Pathologist) respectively, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture.

[2] Numbers in parentheses refer to literature cited.

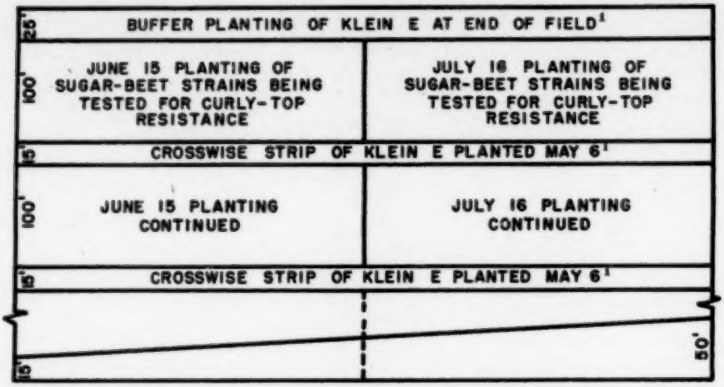
BUFFER PLANTING OF KLEIN E AT END OF FIELD[1]
25'
JUNE 15 PLANTING OF SUGAR-BEET STRAINS BEING TESTED FOR CURLY-TOP RESISTANCE
JULY 16 PLANTING OF SUGAR-BEET STRAINS BEING TESTED FOR CURLY-TOP RESISTANCE
100'
CROSSWISE STRIP OF KLEIN E PLANTED MAY 6[1]
10'
JUNE 15 PLANTING CONTINUED
JULY 16 PLANTING CONTINUED
100'
CROSSWISE STRIP OF KLEIN E PLANTED MAY 6[1]
10'
50'
25'

Figure 1.—Diagram of part of 1953 experiment field showing Klein E planted in crosswise strips and as a buffer at end of field.

[1] Diseased beet roots from previous season transplanted in single row 44 inches apart in crosswise and buffer strips.

Results

Table 1 shows results of the reaction of some well known varieties to a moderate and a drastic curly top exposure.

Table 1.—Reaction of Some Sugar Beet Varieties Under a Moderate and a Drastic Curly Top Exposure.

Variety	Moderate exposure 1952 Planted July 1 Curly top grade[1] in Sept.	Drastic exposure 1953 Planted June 15 Curly top grade in Sept.
Klein E. (SL 1-300)	8	10
U. S. 33 (SL 333)	6	9
U. S. 22/3 (SL 96)	4	7
Beta trigyna	0	Definite symptoms
Beta patellaris	0	do.

[1] Curly top grades 1 to 10 represent successive degrees of injury; 0 represents no injury and no obvious infection.

In 1953 there was almost perfect timing in bringing together factors natural to the area and the experimental procedure which produced the most drastic curly top exposure ever observed by workers on the curly top problem. The disease exposure was so severe that it swept the field clear of all but the most highly resistant forms. For this reason it was not possible to make any selections in any but the most highly resistant varieties.

By use of specially treated seed (6) furnished by Dr. Helen Savitsky, excellent stands of beets from two wild species, *Beta trigyna* and *Beta patellaris* were obtained in the June 15 planting. As far as can be determined, this is the first report of these two highly resistant *Beta* species taking curly top under field conditions. *Beta patellaris* has been reported immune to curly top (2). The 1953 exposure was so severe that many plants in these

two species showed what appeared to be curly top symptoms. By use of non-viruliferous leafhoppers fed on leaves of these plants, test inoculations were made to new healthy sugar beets under careful control at the Riverside, California, laboratory. These tests definitely established that *Beta trigna* and *Beta patellaris* plants exposed to curly top under the severe disease exposure at Jerome, Idaho, were infected with curly top.

Some *Beta patellaris* plants were dwarfed in August and by September the vascular tissue in the stems turned black but there was no leaf distortion. It was of interest to note that these *Beta patellaris* plants were excellent leafhopper hosts and hundreds of leafhoppers were observed feeding on the relatively large single plants.

Beta trigyna plants showed vein clearing in August and some vein swelling in September. By October *Beta trigyna* gained remarkably and showed little injury, whereas the large *Beta patellaris* plants became badly injured. After the middle of October further comparison between these two species was impossible, because *Beta patellaris,* which is very susceptible to frost injury, was frozen and killed. *Beta trigyna,* on the other hand, is very resistant to frost injury and it continued to grow and made still further recovery. By November 1 the *Beta trigyna* plants had recovered so well that they showed only a trace of curly top injury.

Discussion

Spring temperatures in 1953 were abnormally low. Average temperatures compared to normal were —2.0° F. for April, —4.4° F. for May and —1.6° F. for June. The precipitation in May and June was above normal. These conditions were very unfavorable for the development of curly top and, consequently, the epidemic in the crosswise strips planted May 6 was slow getting under way. On the other hand, temperatures for the rest of the year were abnormally high, with not more than a trace of precipitation in July, August and September. Both the low precipitation and high temperatures of July, August and September were very favorable for the rapid development of curly top.

Data on leafhopper migrations were supplied through the courtesy of J. R. Douglass (3). These data, obtained from sugar beet fields similarly located to the experimental field (*i.e.,* close to the desert breeding area), showed that the 1953 beet leafhopper (*Circulifer tenellus,* Bak.) population ranged from three leafhoppers per 100 plants on May 4 to 791 per 100 plants on July 3 when the peak was reached. Combinations of factors favorable for the development of a drastic curly top epidemic in these plantings were: abnormally high temperatures, low humidity and an average beet leafhopper population plus virulent forms of virus from adjacent earlier crosswise-planted beets. By the end of July it was quite obvious that the 1953 epidemic was going to be the most severe yet produced in our experimental fields.

For improvement of curly-top-resistant sugar beets, there are reasons for making outcrosses to curly-top-susceptible varieties for incorporation of other desired characters, such as increased yield, sucrose content, greater adaptation to a range of environmental conditions, resistance to other dis-

eases, and incorporation of the monogerm character. It has been observed that, in making hybrids to be grown in curly top areas, if one parent is susceptible, the higher the curly top resistance in the other parent the greater the probability of success.

In the development of higher resistant varieties from hybrids between susceptible and resistant types, it has been found that the selection process needs to be several short steps rather than one big step, because even if a few roots do survive a severe expo.ure it may be impossible to produce seed from them. It takes about four successive selections for recovery of satisfactory resistance, depending upon the method used and the degree of resistance sought. The curly top exposure for the first selection should be moderate, the second relatively heavy, the third severe, while the fourth should be a drastic exposure. This drastic exposure is required to bring out small differences in curly top reaction between individual beets and to show differences between different highly resistant varieties.

Summary

In 1953 the artificial curly top epidemic in the experimental beet breeding field was so extremely severe that it completely annihilated all but the most highly resistant sugar beet material. On the other hand, the yield of the commercial crop in southern Idaho was the highest on record. This seemingly paradoxical situation came about by the almost perfect synchronization of factors favorable to growth of beets in early, normal, commercial plants on the one hand, and to unfavorable conditions for survival and growth of beets under the artificial conditions set up in the experimental field.

This experience emphasizes the advisability of sugar beet breeders maintaining the highest possible degree of curly top resistance and combining this with other desirable characters, because: 1. the curly top disease may suddenly make its appearance in areas where normally it does not occur; and 2. it may appear under conditions very favorable for the development of the disease, but at the same time unfavorable for the best development of the sugar beet crop. Under either of these extreme conditions, curly top will still take some toll, even from varieties relatively resistant to curly top.

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Possibilities of Breeding for Tolerance Against Virus Yellows and Beet Eelworm

H. Rietberg[1]

Virus yellows causes serious losses in the beet growing areas of many parts of Western Europe, the Netherlands inclusive. On the other hand, in our country beet eelworm is present in many fields in our best beet growing areas.

As direct control of both diseases is very difficult, we have turned our attention to the possibilities of breeding tolerant plants. To prevent misunderstanding it should be mentioned that in Europe the term "tolerance" more or less covers the same idea as the term "resistance" in the U. S. Tolerant plants are plants which, although they are infected by a disease, have lower losses in yield and quality than other plants of the same species.

The work on virus yellows breeding started in 1944, but the first few years were not very encouraging. However, we improved our techniques and methods, and since 1950 we get satisfactory results. In those later years, all our breeding research work has been carried out under supervision of our pathologist, Dr. J. A. Hijner.

A problem with virus yellows under our conditions is that we never get all our plants in the field infected at the same time when we leave it to nature. This is due to the behavior of the vector (aphids). It is necessary to get all plants infected in the same stage, as the stage of development of the plant at the moment of infection has great influence on the development of symptoms and on the final level of losses.

To overcome this trouble two methods were available:

1. Artificial infection with aphids in the greenhouse.
2. Artificial infection with aphids in the field.

Experiments showed us that greenhouse work was not sufficient. Under our conditions of light, humidity, etc., it is very difficult to get clear symptoms on all plants. Therefore, we abandoned the greenhouse-infection tests and relied fully upon the field work.

The plants to be tested are sown in square blocks, each containing 2,000-2,400 plants. These blocks are surrounded by a double row of oats to separate them from the farmer's field and from the other blocks. These rows of oats prevent the spreading of virus from our plots to neighboring beet fields. We have those plots always on the same farm, not far from Bergen op Zoom, and the fact that the farmer (Mr. A. Vos, Vinkenbroek, Roosendaal) is still fully cooperative shows that he has not suffered too much from the virus reservoir we build on his farm every summer.

Early in June all plants have to be infected with virus-carrying aphids. We keep our stock of virus in greenhouse plants infected with a known mixture of virulent strains, while the aphids are wintered over on sprouting tulips and in spring are put on the beet plants. We never use field plants as a source of infection, as then the virus strain is not sufficiently known and other viruses may also be present.

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[1] Director, Instituut voor Rationele Suikerproductie, Bergen op Zoom, Netherlands.

All plants are infected on the same day. This certainly takes a lot of work, but we manage to get it done by sending out a whole group of our staff. The weather has to be chosen carefully. By preference we do this on a calm and dry day. In this way we practically always get a 100 percent infection. After a few days the plants are sprayed with an insecticide to kill the aphids.

As soon as symptoms appear on each plant, the total number of leaves and the number of yellow leaves is counted. This is repeated several times during the season. Also, the general aspect of each strain of beets in the experiment is described at regular intervals. In cases of doubt, symptoms are checked by means of the serological reaction.

The best plants are chosen as mother plants for single plant progenies. Weight, sugar content, noxious nitrogen and ash content are analyzed for each strain or progeny.

Even with this careful study, mistakes can be made, one of the main reasons we have found being the fact that there is no direct correlation between the intensity of the yellow color of the leaves and the losses in yield.

The progress we have made since 1948 is illustrated in Table 1. In this table M 17 is one of our inbreds highly susceptible to virus yellows. A, B and C are our best commercial varieties, while the others are our own inbred lines.

Table 1.

	Root weight per beet gms.	Sucrose %	Noxious N	Virus yellows (10 = green, 1 = total yellow)
M 17	226	15.07	51	3½
A	340	14.90	63	3½
B	326	15.15	69	3
C	346	14.60	47	3
76	372	15.42	48	7
94	475	13.85	53	7½
96	446	14.78	57	7
107	435	15.18	50	7
166	433	15.00	48	6½

These figures give some indication that, by breeding, plants can be obtained which suffer less from virus yellows. We have selected in this table a few numbers at random but could add quite a few other strains to this list.

Not much is known about the inheritance of this tolerance, but there are indications that this is a complex problem.

Another interesting phenomenon is that in our infection plots the plants suffering badly from virus yellows often are attacked heavily by Cercospora, even strains which in virus-free conditions are not very susceptible to this disease.

For sugar beet eelworm tolerance breeding there are at least two possibilities. With virus yellows no immune plants have been found, but the wild species *Beta patellaris*, *B. procumbens* and *B. Webbiana* are im-

mune to beet eelworm and we should try to introduce this immunity in commercial beets. On the other hand, the possibility should not be overlooked that variations in susceptibility might be found in our normal beet varieties.

Numerous crossings were made between sugar beet and the three wild species mentioned above. Although thousands of viable seeds were obtained, the seedlings mostly died in or shortly after the cotyledon stage. The same difficulty has already been described by Dewey Stewart (1)[2]. Various treatments were tried on the seedlings, but without success. Finally in 1952 Hijner succeeded in grafting the young seedlings on stems of *B. procumbens*. Some died, some survived and started growth. One plant formed several flowering branches in 1953. The cross had been made with a male sterile sugar beet and the flowers of the F_1 also proved to be male sterile. Although this plant was pollinated with various types of pollen, no viable seed was formed.

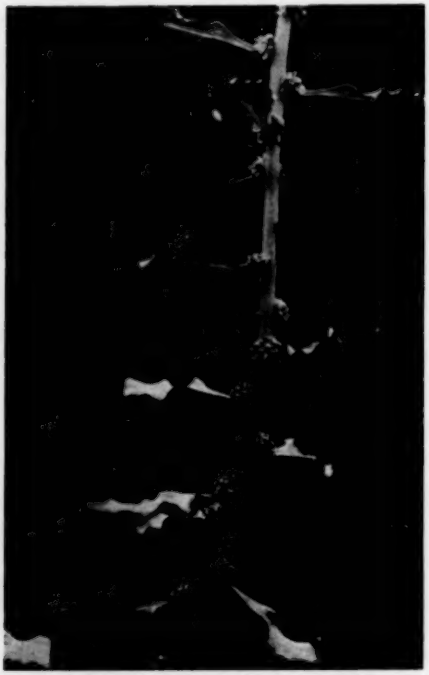

Figure 1.—Sugar beet x B. Webbiana, flowers on F_1 plant.

The leaves of this plant are more or less intermediate between sugar beet and B. Webbiana. The flowers more or less are formed in clusters and not as single flowers as in the wild parent.

[2] Numbers in parentheses refer to literature cited.

Other graftings have been made in 1953 and several of these are growing vigorously, but have not yet reached the flowering stage.

We will continue this work and hope others will do the same, as introduction of immunity would be the best solution of the nematode problem. Under an immune crop the nematode population gradually dies, while under a tolerant crop the population will remain constant or even build up.

We have, however, not neglected the search for eventual tolerance in commercial beet varieties. Here again the technique to be applied gives difficulties, for in the field, even when there is a heavy infestation, the distribution of cysts is too irregular to get a reliable test for individual plants.

Figure 2.—Sugar beet x B. Webbiana, typical intermediate leafshape of F_1 plants.

Den Ouden, a young collaborator of Dr. Hijner, now has worked out a test method which can be used in the greenhouse. First, seedlings are grown in pans with silversand, while to each seed the same number of cysts is added. After 6 weeks all these young plants (several thousand in a few square yards) are carefully taken out of the sand. Those plants on which only a few cysts have been formed are planted again in small pots (2-inch diameter) in sandy soil and cysts added for a second time. After 6-8 weeks the development of cysts on the roots is checked again and the best plants then are planted in large pots, again with cysts. Per 10,000

plants tested, 6-10 plants are left after passing the third test. Those are used for producing single plant progenies which come into the test again. The outcome of this work is not yet clear, for apart from the number of cysts on the roots, other factors have to be taken into consideration also.

This method seems to be cumbersome, especially as enormous quantities of cysts of good quality have to be stocked. But it has the great advantage that in a short time large numbers of plants can be tested under conditions which guarantee an equal chance of infection for each individual plant.

Further improvements of this system are in development and will be applied in 1954.

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Breeding for Resistance to the Sugar Beet Nematode

J. F. SWINK[1]

The sugar beet nematode *Heterodera schachtii* has long been a menace to the sugar beet industry in the Arkansas Valley and continues to become worse year by year. Control measures are urgently needed. The best solution would be a nematode-resistant beet variety. Breeding for resistance has been tried in Europe with some success (1)[2], and Rietberg (2) also has reported differences in resistance between inbred lines. The purpose of this paper is to report the work done in the past three years on selection for resistance to this disease by the American Crystal Sugar Company[3].

In 1950 a farmer[4] near Vineland, Colorado, had a heavily infested field from which he selected 59 roots which appeared to have tolerance to the disease. These roots originated from the variety U. S. 215 x 216 and were turned over to the American Crystal Sugar Company as breeding stock.

The roots were individually weighed and analysed for sucrose and sodium content. After careful selection 43 beets were planted in the greenhouse for breeding work. The plants were pair-bagged to obtain as much seed as possible for replanting in a nematode-infested field. Many plants did not bolt and at the time of seed harvest in the spring of 1951 only 16 plants produced self-pollinated seed and only four pair-bagged seed lots were obtained.

The open-pollinated plants were harvested separately and planted with the pair-bagged material and the parent variety in a field where the year before nematode had been severe. There was good emergence, but as the season progressed noticeable differences were evident in favor of the selections for both stand and vigor.

In October, 1951, roots were harvested from all lines which appeared to have tolerance to nematode. One hundred and five roots were harvested and from this selection 46 were planted in the greenhouse in December, 1951, and 59 were saved for a mother group seed increase for the 1952 spring planting.

Due to curly top in this material, only four inbred and four sib lines were obtained. These were planted in the summer of 1952 with the seed remnants of the 1951 greenhouse work (11 open-pollinated lines) plus four commercial varieties. Nematode was severe in 1952 and differences in the selected lines were noted. From this nursery 248 rather small roots were harvested. These roots were planted in the greenhouse in Decembr, 1952. This included two self lines and four sib lines along with 11 open-pollinated lines and four checks.

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[1] Station Superintendent, American Crystal Sugar Company, Rocky Ford, Colorado.

[2] Numbers in parentheses refer to literature cited.

[3] Acknowledgment is due to Dr. C. W. Doxtator and Dr. R. E. Finkner for assistance in this breeding work.

[4] Earl Hartman, Vineland, Colorado. All selections to date have been made and tested on Mr. Hartman's farm.

All of these roots were pair-bagged in the greenhouse for seed production and 57 different sib lines were obtained for testing in 1953. These were planted in May with three mother lines from the group 2-413, and three inbred lines plus two commercial varieties for reselection purposes. Roots were harvested in September, 1953, from 29 of the 57 lines, three M lines and both commercial check varieties. These roots were planted in the greenhouses in December, 1953, for further breeding.

In 1953 six of the largest mother progeny seed lots obtained from the field group 2-413 were put in an M line test along with a bulk lot of all mother lines, and a commercial variety. This test was flooded, so no yield comparisons could be made. However, root selections were made, taking all beets possible from each line. One line was outstanding in the number of large beets produced when compared to the check, and the 2-413 bulk, as shown in Figure 1. The check and one other line were the poorest selections in number of large roots.

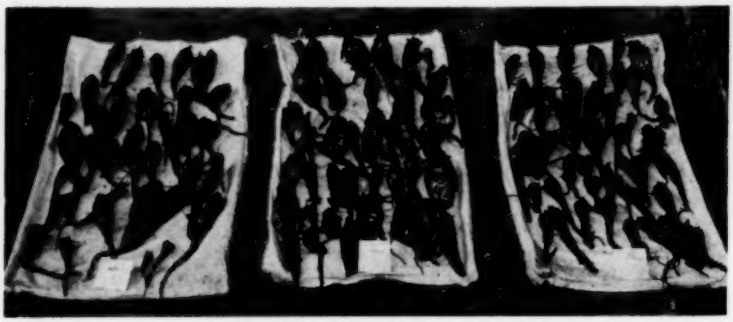

Figure 1.—Three of the lines selected from the replicated test. Left to right: bulk of six mother progenies, resistant line, and check variety.

In the summer of 1953 an area in a farmer's field south of Rocky Ford, Colorado, was observed to be severely and uniformly infested with nematode. Since there were a few live individuals which were surrounded by nearly dead plants, selections were made in this area. All 102 beets obtained were covered with nematode cysts, but the average weight was one and one-half pounds per beet. Figure 2 shows the most outstanding beet in the infested area.

Summary

Nematode has long been a disease which has caused severe loss to the grower of sugar beets. Soil fumigation has proved costly and only works under the most ideal climatic and soil conditions. Since breeding for resistance to disease has been generally successful in crop plants, it was decided to make a determined attempt to find out whether resistance, or tolerance, could be obtained. It is the opinion of the author that a reasonable degree of tolerance has been obtained in the past three years' work.

Because of the encouraging prospects, selection work in this project is being increased, and a permanent nematode disease nursery is being set up near Rocky Ford. Further, attempts to hybridize resistant wild types with sugar beets are being greatly expanded.

Figure 2.—The most outstanding beet in the 1953 selection field.

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Evaluation Tests in 1953 of U. S. 400 and Related Black Root- and Leaf Spot-Resistant Varieties of the U. S. Department of Agriculture[1]

G. H. Coons, Dewey Stewart, H. W. Bockstahler, G. W. Deming, J. O. Gaskill, G. J. Hogaboam and C. L. Schneider[2]

Agronomic evaluation tests as conducted in 1953 included:

A. U. S. 400 and another black root-resistant variety, both of which were developed from U. S. leaf spot-resistant varieties through repeated selections of outstanding individuals under severe black root exposures

B. three hybrids—1. the F_1 between a leaf spot-resistant inbred U. S. 225 MS) and a black root-resistant variety as pollinator, and 2. the F_1 between U. S. 225 MS and a highly productive line as pollinator, and 3. U. S. 216 MS x U. S. 226, a commercial production of this hybrid and

C. an increase of the sugar x garden beet hybrid as bred by Deming.

In all tests, comparisons were made with European check, obtained by growing seed from a pool of 9 European brands, and a local variety as supplied by the cooperators.

Tests as conducted by members of the Sugar Plant Investigations staff and by cooperators in the sugar beet industry at a total of 13 locations are reported. The cooperators in research organizations of the industry who contributed data are H. E. Brewbaker and H. L. Bush, Great Western Sugar Co. (tests at Longmont and Fort Morgan, Colo.); C. W. Doxtator, R. E. Finkner and D. B. Ogden, American Crystal Sugar Co. (test at Mason City, Ia.); J. M. Cass, Canada and Dominion Sugar Co. (test at Wallaceburg, Ont.); Clare Irvin, Lake Shore Sugar Co. (test at St. Louis, Mich.); G. E. Nichol, Monitor Sugar Div. (test at Bay City, Mich.), and Perc A. Reeve, Farmers and Manufacturers Beet Sugar Assoc. (tests at Saginaw and Bay City, Mich., and at Fremont, Ohio).

The varieties in the agronomic tests were as follows:

SP 521601-01	U. S. 225 MS (LSR) x U. S. 1177, (Black Root Res.)
SP 521602-01	U. S. 225 MS (LSR) x Line "D" (SP483-0 (LSR)
Accession 1234	Increase of SP50A1-00, Black Root Res. (West Coast No. 2200)
U. S. 400	Accession 1241, Increase of SP50B3-0, Black Root Res., (West Coast No. 2309)
U. S. 216 x 226	Accession 1242, Commercial production

[1] Investigations on leaf spot and black root resistance are conducted in cooperation with the Colorado, Michigan, and Minnesota Agricultural Experiment Stations, and in cooperation with beet sugar companies which are members of the Beet Sugar Development Foundation. The F. & M. Beet Sugar Association, through the Foundation, supports this research.

[2] Principal Pathologist, Senior Agronomist, Pathologist, Agronomist, Pathologist, Agronomist and Pathologist, respectively, Sugar Plant Investigations, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture.

Deming 520	Accession 1243, Sugar x garden beet hybrid
European Check	Originally grown from a pool of seed of 9 European brands, since then produced by direct increase.
Local	Supplied by cooperators: In Colorado tests, G.W. 359-51R, and G.W. 359-52A; at Mason City, Ia., Amer. Cryst. 2; at Stewart, Minn., Amer. Cryst. 3-S; tests in Mich., Ohio, and Ontario, Com'l U. S. 215 x 216/3.

In 1953 Cercospora leaf spot was late in developing but severe enough to permit readings to be made at Fort Collins, Colo. (test under sprinkler system), Fort Morgan, Colo., Mason City, Ia., and Wallaceburg, Ont. The susceptible European check in the two Colorado tests read 5.6 and 6.7 respectively on the customary scale of 0 to 10, and its acre yields of sugar were significantly low. At Mason City, Ia., Stewart, Minn. (late infection), and Wallaceburg, Ont., the same relationship was shown. Leaf spot was not an important factor in the other tests.

In the two Colorado tests in which leaf spot was a factor the two leaf spot-resistant varieties (SP 521601-01 and 521602-01) were significantly better in sugar yield than the two varieties, U. S. 400 and Accession 1234, in which resistance to leaf spot and to black root were combined. This was not shown, however, at Mason City, Ia., or Stewart, Minn. (light leaf spot), where both leaf spot and black root were factors.

In the Colorado tests, including those in which leaf spot was severe enough to permit readings, the local variety, GW 359, either 51R or 52A, continued to give outstanding performance.

Attention is called to SP 521601-01, the hybrid between U. S. 225 MS and U. S. 1177 (SP 48B3-0), the latter being the black root-resistant variety from which U. S. 400 is a reselection. In nearly all locations this hybrid gave outstanding performance, yielding as an average, over all tests, 14.7 percent more sugar and 9 percent more roots per acre than the European check. It tested, as an average, 5.1 percent higher in sucrose than the European check, taken as 100 percent. In the production of SP 521601-01, the parent, U. S. 225 MS, was rogued to leave only male sterile plants so that presumably all plants were hybrid.

The performance of the hybrid is considered especially important in showing that when male sterile equivalents of varieties or strains which carry certain desirable characters, such as monogermness, non-bolting, leaf spot resistance or other characters become available, then a type with high black root resistance may be utilized advantageously as a pollinator to contribute this quality also.

The sugar x garden hybrid (Deming 520) in most tests had a poor stand but in spite of this made a strong showing in acre yield of roots. However, it was low in comparison with others in sucrose percentage. As a mean of all tests it produced slightly more sugar per acre than the European check. The performance in these tests confirmed previous reports by Deming

and others as to capability of the variety to give high root yield. It was included in the tests to familiarize cooperators with its globose root type. Work is underway to improve its sucrose percentage while retaining the characteristic shape and, it is hoped, high productiveness.

The performance of U. S. 400 is of chief interest to the sugar beet districts in which black root is a serious factor. As an average of all experiments this newly released variety gave 7.7 percent more sugar production and a 3.3 percent higher acre yield of roots than the European check. In sucrose percentage it was 4.2 percent superior, maintaining the high quality characteristics of the black root-resistant selections.

Opportunity was afforded in some tests in Michigan and Ontario to determine its performance under conditions of severe black root exposure, notably the tests at St. Johns, Mich., Bay City, Mich., and Wallaceburg, Ont. Black root was reported as severe at the first two locations and judging from the stands was a factor at the other. In the three tests U. S. 400 had significantly better stands than the European check. In the three experiments the plant populations shown for U. S. 400 indicated nearly full stands. In the tests at St. Johns and Wallaceburg, U. S. 400 was highest in acre yield of sugar and was second at Bay City, being exceeded by SP 521601-01, the hybrid between a leaf spot-resistant inbred and a black root-resistant variety already discussed.

In the tests at Fremont, Ohio, St. Louis, and Saginaw, Mich., there was little exposure to black root and stands did not differ significantly among the varieties. Futhermore, leaf spot was not a factor. These tests therefore give some indication of the productivity of U. S. 400 in absence of disease. At the first two locations it did not differ significantly in acre yield of sugar from the highest yielding variety (SP 521601-01) but at Saginaw it was significantly lower than SP 521602-01. It was not significantly less productive in this test than SP 521601-01.

Seed of U. S. 400 was produced in 1953 in amounts adequate for abundant commercial testing in the coming season. The plantings for commercial seed harvest in 1954 were made largely with stock seed of U. S. 400. There should therefore be ample seed to meet grower demand in 1955.

Table 1.—Acre Yields of Gross Sugar (Pounds) in Agronomic Tests in Michigan, Colorado, Iowa, Minnesota, Ohio and Ontario in 1953. Data Are Given as 8-Plot Averages, Except as Noted.[1]

Location	Reported by	SP 521601-01	SP 521602-01	Bl. R. Res. Acc. 1234	U. S. 400 Acc. 1241	U. S. 216 x 226 Acc. 1242	Deming 520 Acc. 1243	European Check	Local[2]	Genl. Mean	LSD odds 19:1
Colorado											
Fort Collins	Gaskill; Elder[3]	3717	4060	3169	3212	2965	3446	2977	4244	3474	238
Fort Collins	Gaskill; Elder	5227	5578	4667	4800	4393	5267	5361	5517	5101	240
Fort Collins	Deming; Kintzley	5505	5680	4718	4484	4395	4565	4412	6612	5046	397
Longmont	Brewbaker; Bush	7975	8144	7501	7496	7094	7859	7651	8668	7800	630
Fort Morgan	Brewbaker; Bush	8255	8166	7211	7516	7008	7454	7030	8482	7615	629
Iowa											
Mason City	Finkner; Ogden	6529	6428	6069	6321	5542	5224	5721	6414	6031	806
Minnesota											
Stewart	Schneider	3686	2594	4271	3600	3107	2743	2362	3445	3226	515
Michigan											
St. Johns	Bockstahler	3121	2245	3473	3431	2531	2616	2345	2233	2749	402
St. Louis	Irvin	8134	6694	7880	7602	7516	6788	7428	6812	7357	656
Saginaw	Reeve	6543	7064	6191	6122	5766	6507	6800	6022	6377	694
Bay City	Reeve	6599	5532	5826	6092	5466	5636	5282	5270	5712	547
Ohio											
Fremont	Reeve	8763	8699	8263	8293	7938	8102	7740	7963	8220	635
Ontario											
Wallaceburg	Cass	6696	6524	6331	6848	6454	5702	5287	6005	6231	417
Means of all tests		6212	5954	5813	5832	5398	5531	5415	5976	5765	
As percent of European Check		114.7	110.0	107.3	107.7	99.7	102.1	100.0	110.4	106.5	
Mean Mich., Ohio, and Ont. Tests		6643	6126	6327	6398	5945	5892	5814	5718	6108	

[1] Longmont and Ft. Morgan, Colo., 6 replications.
[2] Local variety at Fort Collins, Colo. (3 tests) GW 359-51R; at Longmont and Ft. Morgan, Colo. 359-52A; at Mason City, Ia., Amer. Cryst. 2; at Stewart, Minn., Amer. Cryst. 3-S; at Michigan, Ohio and Ontario locations, U. S. 215 x 216/3.
[3] Under sprinkler; inoculated with *Cercospora beticola*.

Table 2.—Acre Yields of Roots (Tons) in Agronomic Tests in Colorado, Iowa, Minnesota, Michigan, Ohio and Ontario in 1953. Data Are Given as 8-Plot Averages, except as Noted.[1]

Location	Reported by	SP 521601-01	SP 521602-01	Bl. R. Res. Acc. 1234	U. S. 400 Acc. 1241	U. S. 216 x 226 Acc. 1242	Deming 520 Acc. 1243	European Check	Local[2]	Genl. Mean	LSD odds 19:1
Colorado											
Fort Collins	Gaskill; Elder[3]	12.42	13.94	10.75	10.83	9.98	13.50	11.05	13.57	12.00	0.73
Fort Collins	Gaskill; Elder	17.37	18.85	15.71	16.22	14.67	19.57	18.20	18.14	17.34	0.71
Fort Collins	Deming; Kintzley	17.46	18.68	15.43	15.06	14.67	16.91	16.38	19.34	16.74	1.11
Longmont	Brewbaker; Bush	23.36	24.08	21.63	22.27	20.73	24.84	22.73	25.30	23.09	1.65
Fort Morgan	Brewbaker; Bush	24.04	24.85	21.59	22.04	20.82	25.32	21.20	23.92	22.95	1.66
Iowa											
Mason City	Finkner; Ogden	19.03	18.91	17.24	18.59	16.01	17.23	18.03	18.44	17.94	2.49
Minnesota											
Stewart	Schneider	10.72	7.75	12.30	10.49	9.15	8.90	7.06	9.78	9.52	1.51
Michigan											
St. Johns	Bockstahler	7.81	6.30	8.59	8.55	6.80	7.47	6.10	5.91	7.19	0.95
St. Louis	Irvin	21.45	18.62	20.57	20.28	19.70	20.33	19.46	18.57	19.87	1.57
Saginaw	Reeve	18.96	20.94	17.63	18.00	16.99	21.21	19.39	17.81	18.87	1.96
Bay City	Reeve	18.50	16.48	15.94	17.21	17.62	17.70	15.15	14.96	16.44	1.42
Ohio											
Fremont	Reeve	24.56	25.39	23.67	23.62	22.58	26.60	23.92	22.97	24.16	1.36
Ontario											
Wallaceburg	Cass	19.39	19.60	18.20	19.48	18.12	18.63	17.05	17.60	18.51	1.40
Mean of all tests		18.08	18.05	16.87	17.13	15.99	18.32	16.59	17.41	17.28	
As percent of European Check		109.0	108.7	101.7	103.3	96.4	110.5	100.0	104.9	104.2	
Mean Mich., Ohio, and Ont. Tests		18.45	17.89	17.43	17.86	16.97	18.66	16.85	16.30	17.51	

[1] Longmont and Ft. Morgan, Colo., 6 replications.
[2] Local variety at Fort Collins, Colo. (3 tests) GW 359-51R; at Longmont and Ft. Morgan, Colo. 359-52A; at Mason City, Ia., Amer. Cryst. 2; at Stewart, Minn., Amer. Cryst. 3-S; at Michigan. Ohio and Ontario locations, U. S. 215 x 216/3.
[3] Under sprinkler; inoculated with *Cercospora beticola*.

Table 3.—Sucrose Percentages in Agronomic Tests in Colorado, Iowa, Minnesota, Michigan, Ohio and Ontario in 1953. Data Are Given as 8-Plot Averages, Except as Noted.[1]

Location	Reported by	SP 521601-01	SP 521602-01	Bl. R. Res. Acc. 1234	U. S. 400 Acc. 1241	U. S. 216 x 226 Acc. 1242	Deming 520 Acc. 1243	European Check	Local[2]	Genl. Mean	LSD odds 19:1
Colorado											
Fort Collins	Gaskill; Elder[3]	14.95	14.56	14.73	14.83	14.83	12.77	13.46	15.65	14.47	0.50
Fort Collins	Gaskill; Elder	15.05	14.80	14.85	14.80	14.97	13.46	14.76	15.21	14.74	0.41
Fort Collins	Deming; Kintzley	15.74	15.19	15.27	14.82	14.96	13.45	13.44	17.10	15.00	0.56
Longmont	Brewbaker; Bush	17.07	16.91	17.34	16.83	17.11	15.82	16.83	17.13	16.89	0.62
Fort Morgan	Brewbaker; Bush	17.17	16.43	16.70	17.05	16.83	14.72	16.58	17.73	16.59	0.67
Iowa											
Mason City	Finkner; Ogden	17.36	17.06	17.74	17.41	17.44	15.30	16.04	17.56	16.99	0.81
Minnesota											
Stewart	Schneider	17.14	16.66	17.34	17.11	16.96	15.37	16.62	17.47	16.83	0.39
Michigan											
St. Johns	Bockstahler	19.57	17.76	20.06	19.89	18.38	17.23	18.89	18.55	18.79	0.65
St. Louis	Irvin	18.96	17.96	19.14	18.73	19.08	16.71	19.08	18.34	18.50	0.55
Saginaw	Reeve	17.26	16.92	17.58	17.04	17.01	15.33	17.57	16.93	16.95	0.53
Bay City	Reeve	17.83	16.78	18.28	17.74	17.49	15.86	17.43	17.61	17.38	0.71
Ohio											
Fremont	Reeve	17.81	17.14	17.47	17.55	17.58	15.23	16.14	17.37	17.04	0.75
Ontario											
Wallaceburg	Cass	17.25	16.68	17.38	17.58	17.80	15.30	15.53	17.13	16.83	0.69
Mean of all tests		17.17	16.53	17.22	17.03	16.96	15.12	16.34	17.21	16.69	
As percent of European Check		105.1	101.2	105.4	104.2	103.8	92.5	100.0	105.3	102.1	
Mean Mich., Ohio, and Ont. Tests		18.11	17.21	18.32	18.09	17.89	15.94	17.44	17.66	17.58	

[1] Longmont and Ft. Morgan, Colo., 6 replications.
[2] Local variety at Fort Collins, Colo. (3 tests) GW 359-51R; at Longmont and Ft. Morgan, Colo. 359-52A; at Mason City, Ia., Amer. Cryst. 2; at Stewart, Minn., Amer. Cryst. 3-S; at Michigan, Ohio and Ontario locations, U. S. 215 x 216/3.
[3] Under sprinkler; inoculated with *Cercospora beticola*.

Characterization of Sugar Beet Varieties on the Basis of Their Internal Structure Together with the Effect of Environment on the Variability of Diagnostic Characters in Inbred Lines

ERNST ARTSCHWAGER[1]

The material used in this investigation is represented by 19 inbred lines[2] grown at Fort Collins, Colorado, and in replicated plots at Shelley, Idaho.

The internal structure of a sugar beet root, as seen in cross section, is constant for a given variety and can be used by the breeder for diagnostic purposes, enabling him to discard off types. The type picture of a variety is represented by the type formula (1)[3], and a number of subsidiary characters. Of these, ring number of ring density coefficient are more or less constant while central core and first ring may be disturbingly variable even in pure lines. The size of the core and the diameter of the first ring are variety limited. The core is uniform in some lines and variable in others, and its size is independent of root weight. The diameter of the first ring is more variable and tends to fluctuate with root size.

The characterization of a pure line by the inner structure of the root holds true only for a given environment. The effect of location is most pronounced in the central core and the first ring. With a few exceptions core and first ring were smaller in the Idaho material than in the roots grown in Colorado. Ring numbers were similar for both locations or variable in certain lines (Table 1).

The type picture delimits a selection more closely than could be done by external morphological characters alone; it would aid in keeping the line pure through the elimination of such mother beets as showed distinct structural differences. The type picture will show which characters in the different selections can be relied on to serve as a criterion for purity of type, and for inheritance patterns in making crosses.

The modifying influence of environment on some of the characters has been demonstrated (Table 1), and cognizance of it should be taken. Fortunately only certain lines seem to be affected by environment. For many of the lines the type formula remains essentially the same and the ring density coefficient shows little or no variation.

List of Characters Used in the Construction of the Type Formula
General Appearance of the Cut Surface *in situ*

1. Surface mealy white or ivory; zonation faint or absent.
2. Zonation indicated.
3. Zonation pronounced; flesh often gray or translucent.

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[1] Senior botanist, Division of Sugar Plant Investigations, Agricultural Research Service. Field Crops Research Branch, U. S. Department of Agricultrue.

[2] The writer is indebted to G. W. Deming of the USDA Field Station at Fort Collins, Colorado, for supplying the material used in this study and to Mr. Bigler of the Idaho Sugar Company for shipment of replicated varietal material from Shelley, Idaho.

[3] Numbers in parentheses refer to literature cited.

Table 1.—Mean (M), Standard Deviation (σ) and Coefficient of Variability (CV) of Central Core and Mean (M) of Diameters of First Ring, of Ring Numbers, of Ring-Density Coefficients and Type Formulae of 19 Sugar Beet Selections Grown at Fort Collins, Colorado, and at Shelley, Idaho.

	Central core						First ring		Number of rings		Ring-density coefficient		Type formula	
	Fort Collins, Colo.			Shelley, Idaho			Ft. C.	Shelley	Ft. C.	Shelley	Ft. C.	Shelley		
Selection	M Mm.	σ	CV	M	σ	CV	M	M	M	M	M	M	Fort Collins	Shelley
1	4.2	.58	14	1.8	.26	14	16.6	11.8	10.0	9.8	2.5	2.0	2-5-8-11/11-14	2-5-8-11/11-14
5	4.4	.81	18	3.7	1.03	28	18.8	17.3	7.8	8.0	2.0	1.9	2-5-8-11-14	2-5-8-11-14
34	5.3	.88	17	3.5	.82	23	19.9	18.7	8.5	9.0	2.2	2.1	2-5-7/8-10/11-14	2-6-7-11-14
37	5.3	.82	15	3.3	.79	24	22.9	24.2	7.2	8.2	1.8	1.7	2-5-7/8-12-13	1-4-8-10-13
50	6.5	.86	13	4.5	1.17	26	20.7	17.4	9.8	11.3	2.3	2.5	2-5/6-7-11-14	2-6-7-11-14
51	5.6	.86	15	4.0	1.05	26	21.1	19.1	9.8	10.3	2.1	2.4	2-5-7-11-14	1-5-7/8-12-14
63	5.4	.67	12	2.2	.78	35	15.9	12.7	11.7	11.2	2.8	2.9	1-5-8-12-14	1-5-8-12-14
69	5.5	.75	14	3.0	.97	32	23.1	16.8	8.8	8.7	1.9	1.9	2-5-8-10-13	2-5-8-10-14
83	4.2	.92	22	4.5	1.21	27	18.3	22.9	9.4	10.7	2.0	1.9	2-5/6-7-11-14	2-5-7-12-13
85	3.2	.98	31	3.0	1.34	45	16.2	16.3	12.7	12.0	3.0	2.8	2-5-8-12-14	1-5-8-12-14
101	3.5	.97	28	1.9	.20	10	19.1	16.8	8.2	8.3	1.9	1.8	1-5-8-10-14	2-5-8-10-14
107	7.0	.66	9	6.4	1.17	18	27.3	25.4	7.5	7.0	1.7	1.7	2-5-7/8-10-13	2-5-8-10-13
111	6.3	1.45	23	3.4	.85	25	26.0	17.5	9.4	8.4	2.5	2.1	1-5-8-10-13	2-5-8-10-14
119	7.5	1.35	18	5.3	1.58	30	24.5	20.7	10.5	9.5	2.4	2.3	1-5-8-11-13	1-4-8-10-14
123	3.6	.72	20	3.3	1.66	50	20.1	20.1	7.7	8.4	1.7	1.7	2-5-7-11-14	2-5-7-10-13
131	7.7	1.09	14	5.2	1.34	26	25.5	20.7	10.2	9.5	2.2	2.4	1-5-7/8-12-13	1-4-8-10-13/14
132	8.7	1.45	17	10.5	2.25	21	29.7	31.0	7.4	7.4	1.7	1.6	1-5-7-11-13	1-5-7-12-13
133	7.6	.96	13	5.7	1.42	25	25.9	23.2	10.1	9.5	2.3	2.0	1-5-8-11-13	2-5-8-10-13
142	4.0	.33	8	2.4	.58	24	16.0	16.0	9.9	9.5	2.4	2.2	1-5-8-12-14	2-5-8-10-14
159	4.2	.42	10	....	.....	....	16.5	.....	10.5	.....	2.0	....	2-5-8-12-14	.....

Appearance of Thin Cross Section Against Black Background

4. Zonation indicated.
5. Zonation pronounced; rings distinctly set off from interzonal parenchyma.
6. Rings very prominent with limits of phloem and xylem clearly defined.

Width of Vascular Rings

7. Rings broad.
8. Rings narrow.
9. Rings variable in width; inner rings characteristically broader.

Width of Interzonal Parenchyma

10. Parenchyma bands broad.
11. Parenchyma bands narrow.
12. Parenchyma bands of inner rings conspiculously broader.

Size of First Ring

13. Ring broad with a diameter of 22 mm. or more.
14. Rings medium large.
15. Rings narrow with a diameter of 12 mm. or less.

General Appearance of Flesh and Inner Structure of Sugar Beet Roots as Seen in a Cross Section

Selection 1

Origin Flat Foliage; 11th generation (52-305)[4].

Fort Collins: Flat white or ivory with fading bundles; orange cambium lines; gray parenchyma bands; medium thick core and medium-broad first ring.

Shelley: Flat white with fading bundles; orange cambium lines; gray parenchyma bands; thin core and narrow first ring.

Selection 5

Origin U. S. 30297-0. Probably sixth generation (52-307).

Fort Collins: Ivory cream with fading bundles and deep orange cambium lines; medium thick core and medium broad first ring.

Shelley: Ivory or cream with fading bundles and deep orange cambium lines; broad parenchyma bands; variable core and medium-broad first ring.

Selection 34

Origin Flat Foliage. Seventh generation (52-334). Figure 1, A.

Fort Collins: Red-skinned roots with whitish bundle zones and gray parenchyma bands; few-rayed medium-thick core and medium-broad first ring.

Shelley: Red-skinned roots with whitish bundle zones; white cambium lines; dense bundles; small compact core and medium-broad first ring.

Selection 37

Original Flat Foliage. Eighth generation (52-336).

Fort Collins: Whitish bundle zones with fading bundles; light orange cambium lines; somewhat watery parenachyma bands; medium core but broad first ring.

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[4] This number, and similar ones following, refer to U. S. Department of Agriculture, Fort Collins, Colorado, seed number.

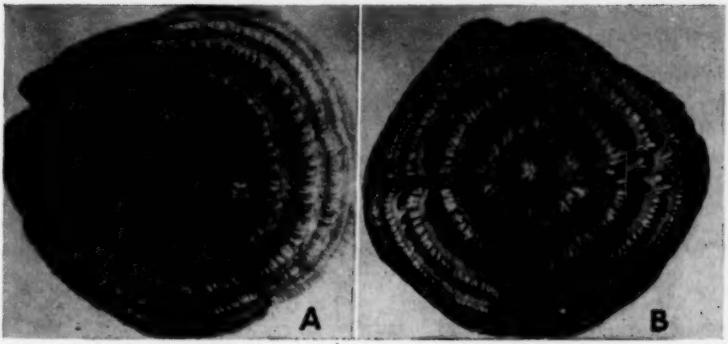

Figure 1.—Selection 34 (left), and Selection 107 (right).

Selection 37 Shelly, Idaho, 1953

	σ	CV
Core = 3.5 mm.	.79	24

First ring = 24.2 mm.
Ring number = 8.2
R. D. Coefficient = 1.7
Formula = 1-4-8-10-13
Whitish bundle zones with fading bundles; orange cambium lines; gray somewhat watery parenchyma bands; small core and broad first ring.

Shelley: White bundle zones; orange cambium lines; somewhat watery parenchyma bands; small core and broad first ring.

Selection 50

Origin sugar variety. At least fourth generation (52-349).

Fort Collins: Uniform ivory cream; white cambium lines; gray parenchyma bands; sparse xylem; large core and broad first ring.

Shelley: Uniform ivory cream; prominent rings; medium large variable core and medium-broad variable first ring.

Selection 51

Origin sugar variety. At least 5th generation (52-350).

Fort Collins: Broad white xylem bands alternating with grayish phloem and parenchyma; white cambium lines; long faint bundles; medium core and large first ring.

Shelley: Flat white flesh; often white xylem bands; slender fading bundles; medium, variable core and variable medium-broad first ring.

Selection 63

Origin Pioneer. More than sixth generation (52-364).

Fort Collins: Numerous narrow rings; white bundle zones; gray parencheyma bands; medium broad core and medium narrow first ring.

Shelley: Numerous narrow rings; whitish xylem bands; small core and narrow first ring.

Selection 69

Origin sugar Sn x unknown red (52-372).

Fort Collins: Deep red parenchyma bands alternating with white bundle zones; medium large core and broad first ring.

Shelley: Red parenchyma bands alternating with white bundle zones; small dense core; medium-broad first ring.

Selection 83

Origin sugar x garden hybrid. Fifth generation from hybrid (52-388).

Fort Collins: Ivory white with somewhat fading bundles; whitish phloem and white cambium lines; medium core and medium-broad first ring.

Shelley: Ivory flesh; long sparse bundles; white cambium lines; somewhat watery parenchyma bands; variable medium-broad core and broad first ring.

Selection 85

Origin Pioneer. Eleventh generation (52-390). Figure 2, B.

Fort Collins: Numerous narrow rings; ivory with dark cambium lines; narrow gray parenchyma bands; small core and medium-narrow first ring.

Shelley: Numerous narrow rings; flat white with white cambium zones fading bundles; variable small core and medium-small first ring.

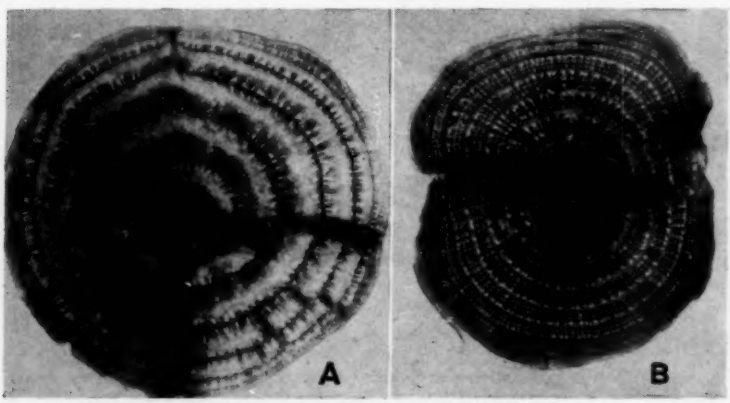

Figure 2.—Selection 101 (left) and Selection 107 (right).

Selection 101

Origin doubtful (52-408). Figure 2, A.

Fort Collins: Uniform white or ivory gray with narrow bundle zones; white cambium lines; small core and medium-broad first ring.

Shelley: Very uniform rings; white bundle zones and orange cambium lines; uniform very small core and medium-narrow first ring.

Selection 107

Origin "Fredricksen." Sixth generation (52-414). Figure 1, B.

Fort Collins: Ivory white with dark xylem; broad slightly watery parenchyma bands; broad core and very broad first ring.

Shelley: Very coarse flat white flesh with prominent confluent dark xylem ends; large core and broad first ring.

Selection 111

Origin Flat Foliage (Strube 20 families). Fifth generation 52-418).

Fort Collins: Whitish flesh with fading bunudles; irreguluar orange cambiumu lines; narrow parenchyma bands; broad core with prominent phloem; ver broad first ring.

Shelley: Flat white with fading bundles; deep orange cambium lines; small compact core and medium-broad first ring.

Selection 119

Origin sugar variety. Sixth generation (52-427).

Fort Collins: Two types represented. Usually narrow white bundle zone with fading bundles and white cambium lines; large core and broad first ring.

Shelley: Two types represented. Usually white narrow bundle zone with slender vanishing bundles; white cambium lines; medium core and medium first ring.

Selection 123

Origin sugar variety. Fifth generation (52-431).

Fort Collins: Ivory cream with white cambium lines; prominent bundles; small core and medium-broad first ring.

Shelley: Ivory cream with deep orange cambium lines, narrow xylem and prominent phloem; variable small core and medium-broad first ring.

Selection 131

Origin unknown. More than fifth generation (52-439).

Fort Collins: Flat white with white bundle zone and dark cambium lines; large core and broad first ring.

Shelley: White ivory with fading bundles, dark xylem, narrow phloem and orange cambium lines; variable medium-broad core and medium-broad first ring.

Selection 132

Sisterline of 131. Possibly Flat Foliage x garden cross (52-440).

Fort Collins: Whitish bundle zones and white cambium lines; gray somewhat watery parenchyma bands; large core and very broad first ring.

Shelley: Flat white with prominent white cambium lines; long fading bundles; gray watery parenchyma bands; very large core and very broad first ring.

Selection 133

Origin F_8 root of Flat Foliage x garden cross (52-441).

Fort Collins: Flat white with white bundle zones and orange cambium lines; gray parenchyma bands; large core and broad first ring.

Shelley: Flat white with white bundle zones, fading bundles; dark cambium lines; variable large core and broad first ring.

Selection 142

Origin sugar variety. Second generation from F_1 of Sn x Sn (52-437).

Fort Collins: White bundle zones with fading bundles and orange cambium lines; uniform medium-small core and narrow first ring.

Shelley: Uniform ivory gray with fading bundles; narrow xylem, broad phloem and broad white cambium lines; small core and narrow first ring.

Selection 159

Sister line of selection 1 (52-474).

Fort Collins: Ivory cream with fading bundles and orange cambium lines; medium-small core and narrow first ring.

Key

A. Flesh red 69
AA. Flesh white
  B. Mean central core 6.3 to 8.7 mm.
    C. Bundle zones broad
      D. Xylem massive 107
      DD. Xylem not pronounced
        E. Ring number small (+— 8) 132
        EE. Ring number medium (+— 10) 50
    CC. Bundle zones with fading bundles 111, 119, 131, 133
  BB. Mean central core 3.2 to 5.5 mm.
    C. Bundle zones broad
      D. Ring number small (+— 8) 34, 123
      DD. Ring number medium (+— 10) 1, 83, 159
    CC. Bundles zones medium or narrow
      D. Ring number large (+— 11) 63, 85
      DD. Ring number medium, bundles fading
        E. Prominent orange cambium lines
          F. Ring number small (+— 8) 5, 37, 101
          FF. Ring number medium (+— 10) 142
        EE. Prominent white cambium lines 51

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Breeding for Improvement of Processing Characteristics of Sugar Beet Varieties[1]

R. R. Wood[2]

Literature dated prior to about 1931, both American and European, makes very scant mention of analysis of sugar beet roots for breeding purposes, for characters other than weight and sucrose content. Dahlberg (1)[3] described the first attempts by this company to apply chemical analysis to the breeding phases of the company's research work. Dudok Von Heel (2) concluded that:

1. Ash content of beets as well as morphological and physiological characters was heritable.

2. Between two beet strains, ash content is not dependent upon sugar content or vice versa.

3. Differences in ash content of various strains are sufficiently great as to effect recovery of sugar.

4. In making comparative tests, recovery of sugar should also be considered. "We are of the opinion that the electrolytic determination (conductivity) of ash content is the most practical."

Schneider (3) emphasized repeatedly the importance attached to breeding for better purity, which at the time was characterized in their breeding work by a low ash and "harmful" nitrogen content, these two characters being the principal ones which during this period were analytically possible of determination on a relatively large scale. The method for harmful nitrogen determination generally employed at that time was described by Stanek and Pavlas (4). Electrical conductivity was employed as a measure of ash content.

Dahlberg (5) states that, in the previous ten years, many thousand such conductivity tests were made on breeding families in the company's stocks. Also, determinations of "harmful" nitrogen and, on a limited scale, true purities were determined, the latter being by "families" in groups of 20 roots.

The first attempts to measure the indvidual mineral constituents of the beet root on a scale large enough to permit effective selection pressures began about 1948 (Dahlberg (6), and Doxtator and Calton (7)) with the development of flame spectrophotometry for rapid determination of sodium and potassium and other cations. Parent-progeny results of sodium selections were given by Brown and Wood (8), and Doxtator and Bauserman (9). The latter investigators in another article the same year (10) studied the interaction of varieties by location for 5 varieties at 6 factory districts, for 9 characters which included all the major mineral elements found in the beet root.

Brown and Wood (8) referred to the development of a chromatographic technique for the determination of raffinose in beets on a fairly large scale.

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[1] The data used in preparation of this report are taken from the extensive beet breeding projects of the Great Western Sugar Company. Th work, therefore, represents at least some effort on the part of almost all the workers, present and past, in the Research Department of the company over a period of several years. Acknowledgment of such effort is made, but a list of all and the work they did would be lengthy and is consequently omitted.

[2] Agronomist, the Great Western Sugar Company, Agricultural Experiment Station, Longmont, Colorado.

[3] Numbers in parentheses refer to literature cited.

Since that time a limited number of progeny tests of raffinose selections have been conducted by this company, and will be discussed later.

In all, the present writing is intended to report later developments in breeding for the improvement of the processing quality of beet varieties as raw material for the factories. As such, the whole effort may be considered as focused on higher purity or, put in another way, fewer mellasigenic substances; for almost all impurities, mineral or organic, which are not removed by carbonation reactions, influence or prevent the crystallization of sucrose from defecated liquors. It is only in these very recent years that instruments and analytical techniques have become available for the more precise measuring of some of the component parts which affect purity. Further, a development by Brown and Serro (11) for determination of "thing juice" purities by an oxalation technique now makes possible large scale analyses for this character itself not heretofore possible by carbonation reactions. This laboratory procedure, as operated on a large scale, will be described later in this report.

Materials and Methods

Sodium

The materials used for studies of the effect of selection for lower sodium content are varieties in the breeding stocks or in commercial production by the Great Western Sugar Company. The data have been accumulated in the course of the breeding and testing program. All analysis for sodium content of roots was done by use of a Perkin-Elmer flame photometer employing lithium nitrate as an internal standard. The testing method used is partly described by Brown and Wood (8), and is essentially a standard procedure, modified for large scale analysis.

Potassium

Determination of potassium content of beets has not been as extensive as for sodium. Analysis for potassium is done by the same procedure, and using the same prepared filtrate as for sodium.

Raffinose

Study of raffinose content of beets has been limited largely to progeny test of one selection, and change in raffinose content during storage; the latter factor is of utmost concern since accumulation of raffinose, in effect determines at what date stored breeding material must be analyzed for most satisfactory selection. The original method for determination of raffinose has been described by Brown (14), but has since been modified (15), to either eliminate deionization of the press juice or use oxalated thin juice filtrate prepared for purity determination, as described by Brown and Serro (11). The latter material has certain advantages as a starting point for chromatographic analysis.

"Thin Juice" Purity

The so-called "thin juice" purity is one of the most important measures of quality employed in factory operation. It measures the amount of impurities being introduced into the process past carbonation. Heretofore, it has not been possible to determine such a purity on a large enough scale to make it usable as a breeding tool. Brown and Serro (11) have developed a procedure employing oxalic acid titration instead of CO_2 gas for carbonation; with such a development it has now become possible to analyze as

many as 500 samples per day by streamlining the procedure for mass production. A "flow sheet" of the operation as modified may be described as:

1. 50 ml. juice is expressed from pulp left after sugar sample is weighed.
2. CaO is added by a dipper as a "milk of lime" suspension, 7 ml. containing ca 1.35 grams CaO.
3. 25 ml. 1.9 N. oxalic acid are added by automatic pipette with stirring.
4. Titration with 1.9 N. oxalic acid is completed to pH 11.2 on glass electrode pH meter.
5. Sample is heated a few moments in water bath at 80° to 90° C.
6. About ½ teaspoon diatomaceous earth is added as filter aid, and sample is filtered with suction on Beuchner filter.
7. Sample titrated with 1.9 N. oxalic acid solution to pH 9.2 on second pH meter.
8. Filter aid again added, and sample gravity filtered on Whatman No. 5 filter paper.
9. Refractometer dry substances determined with Abbe type refractometer and polarization with 200 mm. flow-through type tube.
10. Purity computed by use of previously prepared scales or tables.

Results and Discussion

Sodium

Four mass selections have been made, and progeny tested, using sugar and sodium determinations as a basis of selection. In all cases there was a field and laboratory selection for weight of root in the customary manner. In the case of the 602 variety, selection was made in the field for greater leaf spot resistance, and in the laboratory for lower respiratory rate, in addition to the other considerations mentioned above. Preliminary report on one of these selections was made by Brown and Wood (8) in 1952, on the basis of progeny tests in 1950 and 1951. Data presented at that time are included in Table 1 with subsequent data on the same comparison, in order to cover the results of a longer period of testing.

Table 1.—Parent-Progeny Comparison of Selections Based on Sugar-Sodium Ratio.

Acc. No.	Years tested No.	No. repl. Total	Weighted Averages				Thin juice apparent purity[1]
			Tons	% S.	Gr. S.	% Na	%
304 Parent	4	156	21.80	16.31	7,131	.062	93.82
474 Progeny			21.53	16.71	7,216	.044	93.74
LSD 5% pt.			0.35	0.14	134	.006	.84
305 Parent	2	48	21.13	15.48	6,561	.063	93.40
593 Progeny			20.97	15.95	6,696	.046	94.36
LSD 5% pt.			0.56	0.20	210	.011	0.84
359 Parent	2	120	21.28	16.84	7,145	.053	94.14
602 Progeny			20.73	17.23	7,152	.045	94.23
LSD 5% pt.			0.39	0.17	143	.006	0.84
353 Parent	1	45	19.51	15.72	6,132	.046	93.71
648 Progeny			19.67	16.00	6,304	.032	94.65
LSD 5% pt.			0.59	0.23	208	.006	0.84

[1] On basis of 3 tests in 1953.

In each of the above 4 selections, both a significant increase in sucrose content and reduction in sodium content was obtained in the progeny by comparison with the parent. In 3 of the 4 cases, the progeny was slightly lower in yield than the parent, but in only one of these 3 cases was the difference statistically significant at the 5 percent level. In the fourth case, the progeny exceeded the parent (648 vs. 353) by a very slight amount on the basis of one year's evaluation. As a result of the increased sucrose percentage in the progenies, in each case there is a slight increase in total sugar per acre, but in no case is the difference of statistical significance at the 5 percent level. The effect of this type selection upon thin juice purity will be considered later.

The value of the reduction in sodium content from a processing viewpoint, not considering its association with sucrose content, still appears to be an open question.

Potassium

Potash content of roots has not been found either as variable nor as influential upon other characters as some of the other constituents studied. Doxtator and Bauserman (10) reported a range of only 0.233 to 0.250 percent potassium on beets, or a difference of 7 percent, as averages due to varieties in 6 factory districts. The range due to location, however, was from 0.170 to 0.300 percent potassium on beets, or a difference of 44 percent, with a significant variety x location interaction.

Analytical results from variety tests at 3 locations in 1953, 6 replications per test, 16 varieties, are given in Table 2.

Table 2.—Potassium Content of Beet Roots of 16 Varieties Grown at Three Locations, 1953.

	Potassium, percent on beets			
Acc. No.	Ft. Lupton	Ft. Morgan	Gering	Mean
C304	.251	.273	.270	.265
C474	.258	.260	.285	.268
C476	.248	.261	.262	.257
C305	.251	.282	.280	.271
B593	.242	.266	.238	.249
C359	.251	.277	.266	.265
C602	.243	.259	.266	.256
B619	.234	.248	.241	.241
B620	.252	.263	.290	.268
A53-20	.233	.252	.259	.248
B648	.248	.272	.275	.265
C353	.261	.272	.278	.270
B634	.257	.269	.270	.265
GW388	.247	.276	.274	.266
Kleinwanzleben "E"	.238	.254	.290	.261
Kleinwanzleben "Poly"	.234	.267	.286	.262
Mean	.247	.266	.270	
LSD 5% pt.	.020	.020	.020	.012

It will be observed from the table that statistically significant differences do exist but, as a percentage of the total, such differences appear somewhat small to be of value in selection, even if it were known what selection pressure might be profitably applied, which is not known since potash metabolism is physiologically associated with the well being of the plant.

Raffinose

It was indicated in a previous article, Brown and Wood (8), that selections for higher and lower raffinose content had been made. The roots for this selection were taken from the same population used to make the variety 602 described above in the discussion of selection based on sugar-sodium ratio. Therefore, similar considerations as to weight of root, leaf spot resistance and respiration, apply as for the selection 602.

The analytical results for the amount of raffinose in the selection (Table 3) were obtained after storage of the roots in a root cellar for a period of 12 weeks; this storage period undoubtedly accounts for the high raffinose values obtained. Progeny test results are from roots analyzed at harvest time and, consequently, the values are lower. The first progeny tests of these selections were conducted in 1952, and the second in 1953. The results of the tests, progeny compared with parent, are given in Table 3.

Table 3.—Progeny Performance of High and Low Raffinose Selections, Six Locations, 1952-53.

Acc. No.	Description	Raf. in sel. % on sugar	Beets per acre (tons)	Polarization (%)	Gross S. per acre (lbs.)	Raf. % on sugar
C359	Parent	1.28	21.30	16.07	6,834	0.45
B619	Progeny-low raf. sel.	.85	21.16	16.34	6,909	0.34
B260	Progeny-high raf. sel.	1.53	21.70	16.04	6,964	0.50
LSD 5% pt.			.62	.17	230	.04

The same parent-progeny comparisons were grown in culture solutions in greenhouse in the winter of 1952-53. Fifteen roots from each of two hydroponic culture tanks were analyzed individually for weight and sucrose; pulp remaining after sugar sample was weighed from each root was composited for determination of thin juice purity. A 10 ml. aliquot of filtrate from the purity determination was taken for raffinose determination by the method previously described (14).

Results of analysis for raffinose content of these roots at harvest time are given in Table 4.

Table 4.—Comparison of High and Low Raffinose Selections Grown in Culture Solutions, 1952-53.

Acc. No.	Description	Average wt. per root (lbs.)	Polarization (%)	Raffinose % on sugar
C359	Parent	1.48	16.48	0.095
B619	Low raffinose selection	1.55	15.43	0.065
B620	High reffinose selection	1.77	15.86	0.140

Two points should be considered from Tables 3 and 4; first, the effect of selection pressure for raffinose upon the prime characters of yield and sugar; second, the effect upon raffinose content itself. As measured by statistical methods, there appears to be no change from the parent in yielding ability, as indicated in Table 3. In percent sugar, a significant increase is shown in field trials for the low raffinose selection B619. This is not confirmed by analysis of roots grown in culture media as shown in Table 4.

As for percent raffinose in the field trials (Table 3), a significant reduction is demonstrated for the low raffinose selection as well as a significant increase for the high raffinose selection. This evidence is supported by analysis of the roots from culture solutions as shown in Table 4.

Thin Juice Apparent Purity

Extensive use of this method was made in 1953 for analysis of variety test samples from plantings in the 4-state area in which this company operates. In addition, 60 inbred lines with 4 commercial standards were tested in a cooperative program (13). The most extensive data resulting from such testing as applied to commercial heterozygous types was obtained from analysis of roots of 12 varieties planted at 8 separate locations, with 6 replicates at each location, in Colorado and Nebraska. Average sugar content and weight, together with purity data, are given for these 12 varieties in Table 5.

Table 5.—Harvest Results, 12 Varieties, 8 Locations, 1953.

Acc. No.	Yield Tons per A.	Sucrose %	Apparent purity (%)[1]
C602	21.90	17.25	93.35
GW413R	22.98	16.42	92.98
GW359-52A	22.07	16.85	92.98
C587	21.91	16.94	92.42
B634	22.36	16.35	93.41
C476	20.91	17.38	92.72
C533	21.91	16.54	92.41
C524	21.94	16.33	91.84
GW388	20.79	17.00	92.76
Klein "Polybeta"	21.50	16.43	91.74
GW59-47R	21.82	16.01	93.31
SP50B3-0	21.10	16.43	93.36
LSD 5% pt.	.54	.23	.92

[1] By oxalation.

The data presented in Table 5 constitute only an index of the character of thin juice purity on various commercial or near-commercial types. It is interesting to note, however, that, in such a group, differences of statistical significance do exist.

The economic value of an increase of one point in thin juice purity can be readily calculated; if certain average values are assumed:

1. Non-steffens operation with average molasses true purity of 62.5 percent.
2. Standard total loss of 0.30 percent.
3. Sixteen-percent beet introduced into factory.

Calculations from the above assumptions place a value of 6 pounds more sugar sacked per ton of beets sliced for each increase of one point in thin juice purity.

Of the 60 inbreds and 4 commercial standards, purity range of the 4 standards was from 89.8 percent to 93.4 percent, and for the inbred lines from 82.0 to 94.8 percent, with a difference of 3.0 required for significance at the 5 percent level.

In the course of analysis of single roots for selection on the basis of thin juice purity, a group of 464 roots from a heterogeneous population was studied as to frequency distribution of the purity values in the population. The population curve is plotted in Figure 1.

The portion of the curve above the population mean appears to be limited by the physiological ability of the plant to accumulate and store sugars. Such a limitation is not so clearly evident in the lower section of the curve. This observation is supported by theoretical considerations, if such bio-types as the mangolds are considered.

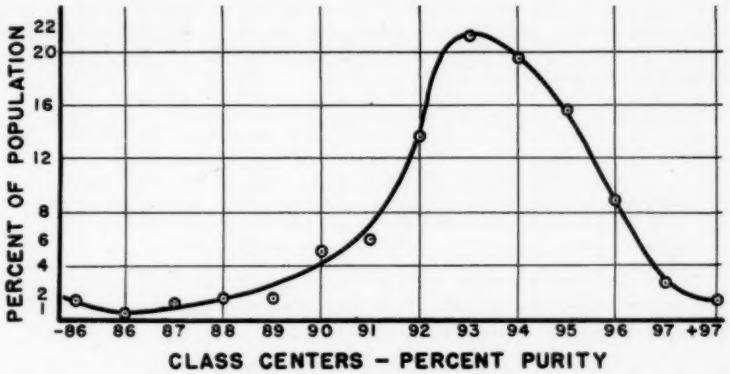

Figure 1.—Frequency Distribution for Percent Purity of Individual Roots.

Association of Thin Juice Purity with Other Characters

Correlation coefficients for a rather lengthy list of characters, chemical and other, were reported in 1952 (12) by a nationwide breeders' committee, for analysis of 56 inbred lines of diverse origin. To this list will now be added (13) the r values for the association of thin juice purities with the various other constituents. From the report mentioned above (13), the r values for thin juice purity with the other characters considered in this paper are:

1. Purity x sugar = .68
2. Purity x sodium = —.52
3. Purity x potassium = —.37
4. Purity x raffinose = —.10

The 5 percent level of significance of r for the above comparisons is 0.25. The association of sugar with purity is not new, and the negative association of purity with sodium is not surprising in view of the known high negative correlation of sodium with sugar content. However, it might be pointed out here that selection on the basis of sugar-sodium ratio, while it did result in significant increase in sugar content of the progeny in all 4 of the cases reported in Table 1, in only 2 of these 4 cases was there a significant increase in thin juice purity in the progenies. It is both of

considerable interest and highly important that raffinose content is not associated with purity. It should be noted, however, that raffinose does have an effect on the actual purity determination in that both raffinose and sucrose are dextrorotatory, and raffinose the greater by a ratio of 1:1.85 in specific rotatory power.

Summary

The use of chemical studies for the improvement of processing qualities of sugar beet varieties has been expanded rapidly with the development of many new analytical procedures in less than a decade. These procedures, as described, have not yet been completely evaluated from an economic standpoint. Several years are needed before testing and seed multiplication will be at the point at which improved raw material can begin to flow to the processing plants.

From the data submitted in this report, the following suggestions are made:

1. The value of the use of a sugar-sodium ratio for selection purposes appears as yet to be an open question. Perhaps a critically designed experiment will be needed to provide an adequate answer.

2. Selection pressures have not been applied to alter potassium content, probably because up to this time no improvement of any particular value is clearly visualized.

3. The possibility of reduction of raffinose content of beets by breeding appears to be very good. The progress shown here in one mass selection suggests that this character may be rather simply inherited.

4. The range of values found for percent purity of thin juice would appear to provide ample opportunity for improvement in this very important character by recognized breeding procedures. This recently developed technique of purity determination appears to be a fairly good integrating mechanism of the many complex factors going to effect purity of the raw material.

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Progeny Test of Sugar Beet Roots Selected for Low Respiration Rate

R. T. NELSON[1]

Methods reported by Nelson and Oldemeyer (1)[2] showed promise of being useful in the sugar beet breeding program for the improvement of storage quality of beets by selection. Whether the method then described for evaluation of respiration rates of individual roots would be useful on open-pollinated lines was somewhat questionable. In this paper are included comparisons of progeny of sugar beet roots selected for low respiration versus those selected for high respiration. Also, there are groups included for standards of comparison which were not subjected to selection regarding respiration rate.

Methods and Results

The method described by Nelson and Oldemeyer (1) was used in this study for determination of respiration rate. From an original group of 3,900 roots collected as a leaf spot selection out of variety GW359, there were respiration rates run on 1,736 individual roots which had been previously screened for desirable weight, sucrose content and low sodium content. In 1951 selfed seed was harvested from plants grown from roots selected out of the above group low in respiration, as well as roots selected as extremely high in respiration. Mother beets of the two groups had on the average equal sugar content and weight.

In 1952, field plantings were made of the 20 inbred lines from the low group and the 20 lines of the high group. The plantings were made in blocks containing 5 single row plots each 25 feet long. Each block contained one plot each of two low-respiration inbreds, one plot each of two high-respiration inbreds, and one plot of the original variety GW359. That fall about 10 roots of each of 50 plots were harvested and placed in the root cellar. In January, 1953, respiration rates were evaluated for all roots stored (see Table 1). The weight and sugar content of these roots was also determined. An analysis of variance showed no significant difference between classes for either weight or sugar percentage.

Following observation of results field plantings were again made in 1953 using seed which had been left over from seed supplies produced in 1951.

A description of classes of material planted follows:

1. Inbred (S_1) of low respiration selection.
2. Inbred (S_1) of high respiration selection.
3. Inbred (S_1) not selected regarding respiration rate.
4. A composite lot of inbreds (S_1) not selected regarding respiration rate.
5. Variety GW359 from which inbreds were started.

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[1] Agronomist, The Great Western Sugar Company, Agricultural Experiment Station, Longmont, Colorado.

[2] Numbers in parentheses refer to literature cited.

Only about half the number of lines in Class 1 and 2 were tested in 1953 as in 1952, due to limited seed supply. Also, in 1953 the results reported in Table 2 were of beets which were not exposed to a long storage period. Harvest date was September 25, 1953, and analysis was completed by October 1. In spite of variations in procedure the results for the two years are reasonably comparable.

Table 1.—Progeny Performance of Roots Selected in 1950 for High or Low Respiration. Results for 1952. Values Are Given in Mg. CO_2/KG./Hour for Sliced Root Tissue at 70° F.

Class and generation	Block 1	2	3	4	5	6	7	8	9	10	Class mean	% of check
1. Low (S_1)	243[1]	209	210	253	227	276	273	228	221	241		
1. Low (S_2)	251	271	195	247	276	266	228	228	248	242	241.65	100.2
2. High (S_1)	305	262	276	239	262	250	273	261[2]	287	303		
2. High (S_2)	322	287	254	290	292	277	316	297	259	290	280.10[3]	116.1
5. Check, Cml	229	253	242	241	243	251	276	218	232	227	241.20	100.0
General Mean											256.94	
C.V. = 8.02												
LSD 5% pt.: Class 1 or 2 with 5 =											16.21	
LSD 5% pt.: Between Class 1 and 2 =											13.24	
LSD 1% pt.: Class 1 or 2 with 5 =											21.75	
LSD 1% pt.: Between Class 1 and 2 =											17.76	

[1] The mean of ten determinations of single roots.
[2] Missing plot value calculated.
[3] Difference highly significant compared with Class 1 or 5.

Table 2.—Progeny Performance of Roots Selected in 1950 for High or Low Respiration Compared with Various Check Classes. Results for 1953. Values Are Given in Mg. CO_2/KG./Hour for Sliced Root Tissue at 70° F.

Class and generation	Block 1	2	3	4	5	6	7	8	Class mean	% of Check, 5
1. Low (S_1)	254[1]	252	195	205	247	229	213	214	226.2[2]	95.3
2. High (S_1)	294	293	242	246	254	243	243	265	260.0[3]	109.5
3. Check (S_1)	283	273	215	258	258	241	247	261		
3. Check (S_2)	288	261	221	235	307	216	227	239	251.9	106.1
4. Check (S_2	261	260	212	248	279	260	212	246	247.3	104.2
5. Check, Cml.	240	230	226	220	262	245	235	240	237.4	100.0
General mean									245.76	
C.V. = 6.17										
LSD 5% pt.: Class 3 with other classes =									13.32	
LSD 5% pt.: Between Class 1, 2, 4, or 5 =									15.38	
LSD 1% pt.: Class 3 with other classes =									17.88	
LSD 1% pt.: Between Class 1, 2, 4 or 5 =									20.64	

[1] Mean of about eight determinations on single roots.
[2] Significantly lower at 1 percent pt. compared with Classes 2, 3 or 4.
[3] Significantly higher at 1 percent pt. compared with Classes 1 or 5.

Differences in respiration rate of progenies of lines from low and high selected groups were statistically significant both years. It was suggested in results of Table 1 that the inbred (S_1) lines as a class might be higher in respiration rate than the open-pollinated class. Following the latter observation an attempt was made to outcross a representative number of inbred lines of each group; however, this was not completed due to failure of the seed crop.

As shown in Table 2 the S_1 generation lines showed higher respiration than the open-pollinated line except for Class 1. When compared with the checks grown as S_1 the selection for high respiration was not as effective as selection for low respiration. A possible explanation for this is that environmental factors, such as wilting and fungal infections incurred during prolonged storage (October to January), may have interfered with the selection for inherent differences in the group originally selected for high respiration. Thus, this group may have contained roots which were unsound due to environmental rather than inherent factors. It has been found that wilting or fungal infections even in a mild degree will change the respiration rate and storage quality of sugar beets.

There was no apparent relationship of respiration rates with yield or sugar percentage. Further studies on this subject are in progress. A point of interest for investigation is the effect of inbreeding and outcrossing on respiration rate of sugar beet roots.

Summary

A selection of two classes was made from the open-pollinated variety GW359. Class 1 was a group of roots showing a low respiration rate. Class 2 was a group of roots showing a high respiration rate. Production of CO_2 by sliced root tissue was used as a measure of respiration rate. The identity of the classes was maintained by bagging and permitting only self-pollination in seed production from selected mother roots. The progeny grown in the field and tested showed a significant difference in respiration rate as measured on slices from marketable roots of the two classes.

The results indicate that the selection for low respiration rate was effective since the respiration rate was significantly lower in the progeny of the low selection (Class 1) when compared with progenies similarly grown (Classes 2, 3 and 4), but not selected for low respiration.

Thus, improvement in storage quality of sugar beets should be possible through breeding. There was no observed adverse relationship of low respiration with other desirable characters. Roots not specifically selected for low respiration rate, and tested in the S_1 generation, showed a somewhat increased respiration rate over the parent open-pollinated variety. This suggests that when comparing lines for respiration rate one should compare only reasonably comparable generations.

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Yield and Quality of Certain Sugar Beet Varieties Harvested at Weekly Intervals

H. L. Bush[1]

Introduction

Some of the results from the variety testing program of the Great Western Sugar Company indicated that the new varieties might have the ability to continue growth under the cool autumn conditions at a different rate than the older varieties, even where a disease factor might not be the contributing factor.

In order to get some pertinent data relative to this possible difference in varietal interaction a date of harvest study was initiated in 1951 covering the period from the last half of August and continuing through November.

Materials and Methods

The test, as designed in 1951, was set up in a randomized complete block arrangement with 10 replicates per week of plots 1 row by 25 feet to be harvested at weekly intervals, covering the period August 20 to November 26. There were 6 varieties included, representing a considerable range in potential yielding ability and sugar content. Weight and sugar content were determined each week. In 1952, the test was continued using the same 6 varieties but with a slightly different scheme for randomization, with 15 replicates per week of plots 1 row by 18 feet for harvest from August 25 through December 1. In order to institute more local control on the sample, the 1953 test included only 4 varieties, and was arranged as a multiple Latin square design with 12 replicates of plots 1 row by 18 feet, to be harvested each week starting August 17 and continuing through November 30. Thin juice apparent purity was also determined in 1953, using a method devised recently by Brown and Serro of the Great Western Laboratory in Denver (1)[2].

Discussion of Results

This report will include only the data for the two varieties which were carried for all three years of test. These varieties have the following characteristics: Variety A is a potentially good yielder with a low sugar content and susceptible to leaf spot. Variety B is leaf spot-resistant with a high yielding ability and rather high sugar content.

The 1951 field was not planted until April 26, while plantings were made approximately one month earlier in 1952 and 1953, and this may offer a partial explanation for the results obtained in sugar content in 1951. Soil variability was rather great in 1951 but there were no diseases evident. In 1952 field was badly affected with nematode, the variations were not very well controlled through the experimental design used, and Variety A appeared to be more adversely affected by the nematode than did Variety B, as judged from top appearance in the field. This may account, in part at least, for the great difference in yielding ability between the varieties for this year. The 1953 data no doubt were affected to some extent by the development of a moderate leaf spot infection on Variety A late in September.

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[1] Statistician-Agronomist, Agricultural Experiment Station, The Great Western Sugar Company, Longmont, Colorado.

[2] Numbers in parentheses refer to literature cited.

The weekly results for each year are presented in graphic form in Figures 1, 2 and 3. The differential yearly effect may be readily observed.

In 1951 and 1952 the varieties developed similarly in yield of roots throughout the period covered, although the curves were somewhat dissimilar for the two years. The highest mean tonnage resulted from the November 5 sampling in 1951, although the high point in sugar content occurred on October 29. The temperature dropped to minus 15° F. on November 2, 1951, which no doubt was the limiting factor for further development that year. In 1952, probably due to lack of moisture and nematode infestation, there was little tonnage increase after September 15, although the sugar content increased fairly rapidly until November 3, with a slight drop indicated after November 10, considering the mean results for the two varieties. In 1953, the maximum mean tonnage for the two varieties was indicated on October 12, while the sugar content continued to increase until November 16, after which killing frosts occurred.

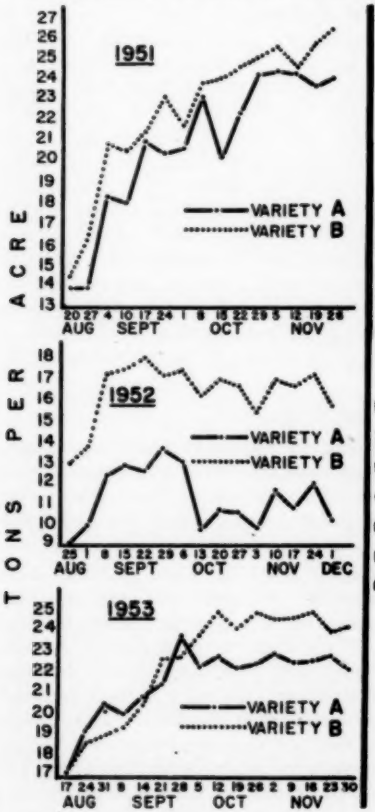

Figure 1.—Tons Beets per Acre.

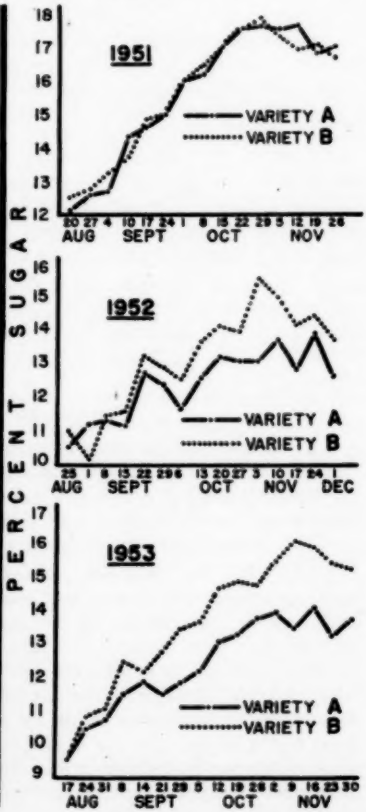

Figure 2.—Sugar Percentage.

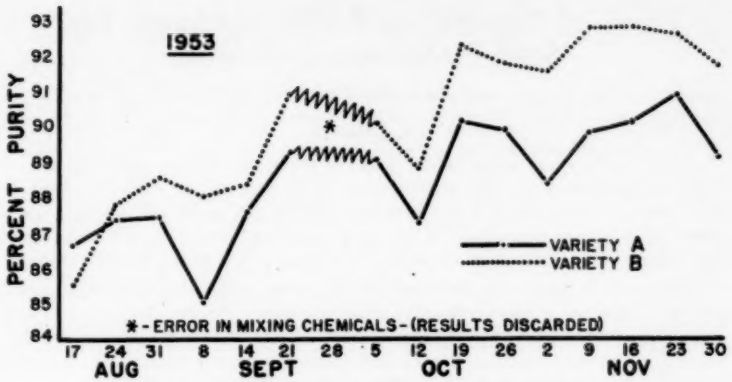

Figure 3.—Thin Juice Apparent Purity (percent).

Since the variety-week interaction is of prime importance, the accompanying data in Table 1 will serve as a guide in interpreting the results.

Table 1.

Var. x Week Interaction	1951			1952			1953		
	F	5% pt.	1% pt.	F	5% pt.	1% pt.	F	5% pt.	1% pt.
Yield of roots	NS	1.34	1.50	NS	1.30	1.45	2.14	1.40	1.61
Sugar content	NS	1.34	1.50	2.50	1.30	1.45	3.92	1.40	1.61
App. purity	—	—	—	—	—	—	1.41	1.40	1.61

The results for 1953 indicate a highly significant interaction between varieties and weeks for yield of roots, although no interaction occurred in either of the previous years for this character. In both 1952 and 1953 there was a definite interaction between weeks and varieties for development of sugar where Variety B, the high sugar variety, continued to increase in sugar content at a more rapid rate than did Variety A. The contrasting results for 1951, as compared with 1952 and 1953, probably can only be explained as an environmental effect, with the possibility of the rather late planting date, previously mentioned, offering some tangible explanation. The interaction for thin juice apparent purity was just significant at the 5 percent level of significance.

Summary and Conclusions

The significant variety-weekly interaction for tonnage in 1953, and for sugar content in both 1952 and 1953, gives evidence that different types of varieties may react differently as the season progresses. This effect may not always occur, however, as shown by the fact that no interaction was found in the other data studied. The importance of considering the date of harvest when evaluating varieties is emphasized by the results of this study.

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Forms of Nitrogen as Related to Sugar Beet Seed Production in Oregon[1]

R. A. PENDLETON[2]

Introduction

In recent years there have been local shortages of some forms of nitrogen fertilizers. Consequently, users have frequently been required to make some adjustments in their fertilizer programs to fit the market situation. This has been of particular concern to growers of sugar beet seed, who normally use 300 to 400 pounds of nitrogen per acre for their crop.

It seemed desirable to test some of the more common commercial nitrogen fertilizers as to their efficiency in production of sugar beet seed under specific conditions. Although results obtained on one type of soil are not necessarily applicable to all types, they may give good indications of results to be expected elsewhere.

Methods of Study

Field plots were established on Chehalis sandy loam soil to study the effects of several forms of nitrogen on yield and germination of beet seed. Sugar beets grown on this soil have a high nitrogen requirement and relatively low phosphorus and potash requirement. Sulfur and boron are known to be limiting (1, 2, 3)[3].

In 1950-51 field plots were arranged in a randomized block design with 7 fertilizer treatments and 6 replications. Fertilizers used were: 1. Ammonium sulfate; 2. ammonium sulfate and sodium nitrate; 3. ammonium sulfate and calcium nitrate; 4. ammonium sulfate and ammonium nitrate; 5. ammonium sulfate and urea; 6. ammonium sulfate and lime; and 7. ammonium phosphate (16-20-0).

A total of 300 pounds per acre of nitrogen was applied to all plots in three equal increments: the first in the fall, the second in early April, and the third in early May. Where two sources of nitrogen were used, an equal amount was supplied from each source. Lime was applied for treatment No. 6 at 10 tons per acre of high grade ground limestone at planting time.

The fertilizers were all side dressed at about 4 to 6 inches to one side of the row and 4 to 5 inches deep. Previous to planting in early August a uniform application was made of 25 pounds of borax and 125 pounds of gypsum per acre.

It had been previously demonstrated that gypsum as the only source of sulfur will not prevent sugar beets on this soil from showing sulfur deficiency symptoms when fertilized heavily with nitrogen[4]. Therefore, fertilizer mixtures were used in which at least half the material supplied sulfur in sulfate form. The gypsum treatment supplied adequate sulfur until the first application of fertilizer was made.

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[1] Approved for publication as technical paper No. 830 by the Director of the Oregon Agricultural Experiment Station and the Chief, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture. Contribution of the Department of Farm Crops and Soils, Oregon Agricultural Experiment Station, and of the Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture.

[2] Agronomist, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture.

[3] Numbers in parentheses refer to literature cited.

[4] Unpublished data, Soils Department, Oregon State College.

Experimental Results

Seed yields and germination percentage of the harvested seed were determined. These data are given in Table 1.

Table 1.—Sugar Beet Seed Yield and Germination Resulting from Fertilizer Treatments.

Treatment	Seed yield	Germination
	pounds per acre	percent
1. Ammonium sulfate	3,535	92.0
2. Ammonium sulfate and sodium nitrate	3,771	94.0
3. Ammonium sulfate and calcium nitrate	3,654	96.0
4. Ammonium sulfate and ammonium nitrate	3,700	97.7
5. Ammonium sulfate and urea	3,606	94.7
6. Ammonium sulfate and lime	3,674	95.3
7. Ammonium phosphate (16-20-0)	3,716	96.5
Difference for significance at 5 percent level	120	2.29

It is apparent that ammonium sulfate alone is not the best fertilizer for sugar beets on this soil. All other treatments except No. 5 produced significantly higher seed yields than ammonium sulfate alone. The mixture with sodium nitrate gave the highest yield but in this trial did not produce a significant improvement in germination.

In this crop there was plenty of time between the last fertilizer application and harvest for all forms of nitrogen to become available. Consequently, the urea or ammonium was not at any disadvantage in this respect. In commercial fields it is common practice to apply some additional nitrogen later in the season with the irrigation. This has not been tried in replicated plots but observations indicate that it is a desirable practice. In all small non-replicated tests, late nitrogen applications, particularly with nitrate-N, have produced seed with indications of improved viability.

Summary

Several sources of nitrogen were tested in field plots for their efficiency in sugar beet seed production. Both yield and germination percentage of the harvested seed were determined.

All treatments included a portion of the nitrogen from a source which supplied sulfur.

The poorest yield and lowest quality seed were produced in plots fertilized solely with ammonium sulfate.

The fertilization conducive to the highest yield of seed did not produce seed with the highest viability.

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The Wild Species of Beta

G. H. Coons[1]

The increased interest in the wild species of Beta as a source of new genes for improvement of the cultivated beet and the availability of seed of many of these forms for use by plant breeders make it desirable to supply a roster of the species arranged to show their natural affinities (Table 1). Some comments on the various species also are made.

Transchel (4) in 1927 established three sections for the genus Beta. Ulbrich (5) seven years later assigned the species to four sections, amending two of Transchels, accepting one (Corollinae), and establishing a new one, "Nanae," for *B. nana*. Ulbrich changed Transhel's section Patellares to Procumbentes and placed *B. atriplicifolia* within this group, clearly an error. Accordingly, in the arrangement of the genus proposed here, Ulbrich's classification is followed in large part but Transchel's clearly defined and valid section Patellares is restored.

The natural distribution of the sections and species of Beta indicates the probable centers of origin. The section Vulgares centers in the eastern Mediterranean region with *B. maritima* occurring in Asia Minor, in the central and outer Asiatic steppes and desert areas and extending eastward to outer India. From the Mediterranean area it extends westward to the Cape Verde and Canary Islands and northward along the Atlantic Coast to the North Sea. It occurs in the Channel Islands and along the coasts of England, Scotland and Ireland.

Other wild species of this section have a more restricted distribution within this broad area. The section Corollinae centers in Asia Minor, its species extending eastward to Iran and westward to eastern Europe. The section Nanae represented by one species is known only from the mountain heights of Greece; especially Mt. Olympus, Mt. Parnassus and Mt. Taygetus. The section Patellares occurs only in the western and outer Mediterranean region and on the Cape Verde, Canary, Salvage and Madeira Islands. *B. patellaris* occurs over this entire region, whereas *B. procumbens* and *B. webbiana* are restricted to the Canary Islands, the latter having been collected only from Las Palmas and Fuerteventura Islands.

Usually the Beta species occur where their salt tolerance and ability to withstand drought give them some advantage over the competitive species. Some of the species occur only sparsely and away from cultivated areas, whereas a few species are more or less troublesome weeds. *Beta maritima* is usually restricted along the Atlantic sea coast to the zone where the salt spray reaches. It occurs as a weed in the salt marshes in Portugal and southern France. Zossimovitch (6) reports it as occurring as a weed in the steppes of USSR, especially in depressions where alkali and salt content is high. *B. patellaris* Moq. was found as a weed in one small garden patch in the Canary Islands, but it usually occurs sparsely among the rocks near the sea shore. *B. atriplicifolia* was found in cultivated fields in southern Spain and was reported to be a troublesome weed.

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[2] Numbers in parentheses refer to literature cited.

Table 1.—Species of Beta.

I. Vulgares	II. Corollinae	III. Nanae	IV. Patellares
vulgaris L.	macrorhiza Stev.	nana Boiss. et Held.	patellaris Moq.
maritima L.	trigyna Wald. et Kit.		procumbens Chr. Sm.
macrocarpa Guss.	foliosa Hausskn.		webbiana Moq.
patula Ait.	lomatogona Fisch. et Mey		
atriplicifolia Rouy			

In Turkey, *B. lomatogona* and *B. trigyna* occurred in wheat fields and occasionally as roadside plants. It is reported that farmers scatter the seeds in the wheat fields to provide themselves with a spring salad plant. Once introduced, the species undoubtedly would persist in the small parcels of land where only wheat is grown, and whose cultivation is only a shallow stirring of the soil. Zossimovitch (6) states that *B. macrorhiza* is commonly found close to villages and that its leaves are prized as a source of food.

The other species of the genus as seen by the writer occur sparsely in such habitats as crevices in rocks, or rather sterile and rather dry soils where competition of grasses and other plants is not serious.

Vulgares

This section of the genus is best known to sugar beet breeders because of the greater attention that has been given in the past to the close allies of the cultivated beet, especially to the sea beet, *Beta maritima*. The other species of this section, *Beta patula*, *B. macrocarpa* and *Beta atriplicifolia*, have also been subjects of study and have been used to some extent in hybridizations.

The type species of the genus Beta is *B. vulgaris* L. In his Species Plantarum, Ed. I, p. 222 (1753), Linnaeus named only this species. Under it, as varieties, he listed *perennis*, *rubra*, and *cicla*, to which were assigned the nine forms of Beta that the old botanist Caspar Bauhin had recognized. Linnaeus makes his variety "*perennis*" synonomous with Bauhin's *B. sylvestris maritima*. As their names would indicate, the other varietal names apply to cultivated forms of beet.

The binomial *B. maritima* was first used by Linnaeus in 1763 in the second edition of Species Plantarum, Volume I, page 322. Here Linnaeus clearly gives *B. maritima* specific rank along with *B. vulgaris* and shows *B. sylvestris* as a synonym. The varietal name *perennis* disappears.

There has been a tendency to consider *B. maritima* L. as simply a form of *B. vulgaris* or that *B. vulgaris* was the cultivated form derived from the sea beet. The thick leaves, sprangled roots with the laterals arising at right angles to the tap root, distinctive growth habit and numerous other characters of *B. maritima* are as distinctive as those characters by which other members of the section are separated as species from *vulgaris*. No useful purpose seems to be served by classing *B. maritima* as a variety or subspecies of *B. vulgaris* unless all the other members of this section are similarly classed as sub-species.

The species of the Vulgares section all hybridize readily with the cultivated forms of beet and some of them with each other. The latter has made

it difficult to obtain and maintain certain species entirely pure. Thus seed of *B. patula* Ait. was collected on Madeira Island in 1935 and plants were grown in the greenhouse. The seed stocks soon became contaminated by outcrossing, especially with *B. maritima,* and new collections from the Madeira Islands are needed. *Beta patula* is an annual or perennial form known only from Madeira Islands and is characterized by its sessile, strap-like leaves.

B. macrocarpa Guss. is an annual form characterized by its extremely large seed balls. This species also apparently hybridizes readily with *B. maritima.* Its distribution is along the Mediterranean coastline and on the Canary Islands. In Spain it was found growing in close proximity with *B. atriplicifolia* but seemed to be entirely pure probably due to differences in the periods of flowering of the two species.

B. atriplicifolia Rouy is a perennial species which is certainly distinct from any others of this section. It is characterized by its small size, its graceful growth habit, its linear-lanceolate leaves and its long spindle-shaped root free from sprangles. The piants have striking red coloration, often shown as streaks on the seed stalk. The stem is not always triangular in cross section as stated. *B. atriplicifolia* was collected by the writer in 1935 and again in 1951 in southern Spain. It occurs there as a weed in the fields. This species has been hybridized with the sugar beet but, so far, does not seem to have conferred any particularly desirable characters.

Corollinae

The species assigned to this section seem to form a good natural group. The characteristic development of a corolla-like perianth makes the flower spikes rather conspicuous.

B. macrorhiza Stev., a characteristic species of this section, was obtained from USSR through the courtesy of N. I. Vavilov in 1936 and was grown in the Arlington greenhouse in 1937 and 1938. The plants were characterized by their very coarse, heavy veined leaves resembling in texture *B. trigyna* more than any other type. The leaves were obtuse at their apices. None of the plants as grown in the greenhouse produced flower stalks. Under inoculation they were shown to be susceptible to both *Cercospora beticola* and to curly top. During the removal of research work on sugar beets from Arlington Farm, Va., to Beltsville, Md., the stocks were lost; when attempt was made to grow the plants from seed, it was found that the seed remnant had lost its viability. It has not been possible to obtain additional material from the USSR.

The writer's recollection is very clear respecting the very large seed balls of this species. Many were very much larger than any of the seed-balls of sugar beet. The glomerule was globose and multigerm. Some seed balls had at least eight or more true seeds.

Our best information about the plant material as furnished to us by Vavilov comes from Zossimovitch (6) who collected the species in the Caucasus Mountains. He states that the species is characterized by large obtuse ovate leaves. These are obtuse at the tip and have a cordate base. The leaves are dark blue green, without wax, and their petioles are short.

The stem leaves are extremely large and those near the apex are either blunt or pointed. The flowers are of a normal type for this section, loosely grouped, several to a cluster. The lobes of the perianth are white and terminate in a hood. The flowers grow to form a seed ball which is very large, having six to eight true seeds, especially those seed balls located at the base of the lower brances. Zossimovitch stresses that flower bracts are large, up to three centimeters in length, the size and shape of the bracts as well as the large size of the stem leaves, giving plants a peculiar appearance.

This description is strikingly at variance with the terse one given by Stevens which characterizes the plant as a perennial with fusiform, multi-crown roots having red flesh; prostrate stems; ovate leaves, mostly obtuse; top most leaves sub-rotund; simple spikes, leafless at top, and with flowers occurring in three's. Zossimovitch states that the red flesh mentioned by Steven must be in error for no such roots were found in his collections in the Caucasus. He further states that he has verified Transhel's studies of plants of *B. foliosa* from Armenia in which Transhel stated that *B. foliosa* of Haussknecht was in fact *B. macrorhiza*. Aellen's (1) description of the species *B. macrorhiza* was apparently based on *B. foliosa* material available to him and does not fit Zossimovitch's description. This nomenclatorial tangle can best be resolved when our collections of *B. foliosa* can be compared with authentic *B. macrorhiza* material. We hope such may be made possible by collections of *B. macrorhiza* in either eastern Turkey or in Iran.

B. foliosa Hausskn. is known chiefly from the original collections made at Salachlu near Egin, Turkey, a place which on modern Turkish maps is Salihli near Kemalye. Scheibe (3) stated that he had found *B. foliosa* near Erzinjan, Turkey, at an altitude of 2,020 meters above sea level. As stated, the description given by Aellen may largely have been drawn from Haussknecht's collections. Aellen accepting Transchel's statement that *B. foliosa* and *B. macrorhiza* are the same species.

The writer visited the place of Haussknecht's type collection and found plants which certainly were not in accordance with *B. macrorhiza* as grown from the Russian material sent us in 1936 or the same as Zossimovitch's description. Hence the name *B. foliosa* is retained to refer to these particular collections pending additional studies. No botanical description of the species has as yet been published.

B. lomatogona Fisch. et Mey. is characterized by its single-germed seed-ball and a leaf shape and growth habit which are distinctly different from those of *B. trigyna*. The species occurs in abundance in Asia Minor and probably eastward. A number of collections were made of this species in Turkey where it occurs as a common weed in wheat fields, usually along with *B. trigyna*.

B. trigyna Wald. et Kit. was first collected in Hungary near the western-most points of distribution of the species. The form which was found is believed to have been of the hexaploid type with 54 chromosomes. The distribution of the species, according to Aellen, is around the Black Sea with a center of distribution in Turkish and Russian Armenia and Georgia. It also occurs around the Caspian Sea and in Persia. Collections have been

made in Crimea and southern Ukraine. The species radiates eastward toward Hungary, Roumania, Slavonia and elsewhere in the Balkan area, Macedonia, and eastern and western Thrace.

Zossimovitch has proposed that the name "trigyna" be restricted to the hexaploid form as found in Hungary and the Crimea and that the tetraploid form (2n = 36 chromosomes) be named *B. corolliflora*. No good purpose is served by such a separation within this species.

B. intermedia as proposed by Bunge and described by Boissier is not accepted as a species. Many botanists have questioned whether this group differed from *B. trigyna* enough to warrant specific rank. There has also been speculation that *B. intermedia* represents a cross or a segregation from a cross between *B. trigyna* and *B. lomatogona*. Zossimovitch in 1934 (6) considered "*intermedia*" a sub-species of *B. lomatogona*, apparently ignoring the single seed character in *B. lomatogona* and the multigerm seed character in *B. intermedia*. The only positive differentiating character from *B. trigyna* is the ovate shape of the basal rosette leaves. These are reported as cordate at the base and as having long thin petioles. Later Zossimovitch (7) considered *B. intermedia* should be retained as a separate species.

Many collections were made in Turkey of Beta forms in which the basal rosette leaves were oval rather than pointed; these resembled *B. trigyna* far more than *B. lomatogona* and would seem to fall within the general range of variation of *B. trigyna*.

Nanae

This section is represented by the single alpine species, *B. nana*. The plants of this species are small, seldom having a rosette of leaves more than 4 inches broad. The solitary flowers occur in axils of small orbicular bracts of the unbranched prostrate fruiting stem. The flowers are single and the seed is single-germed, hard and nut-like. Collections were made in 1951 on Mt. Parnassus from two separate sites. Living roots were brought to the United States. These flowered in the greenhouse, but the seed produced was not viable. The plants proved very susceptible to *Cercospora beticola*. The reactions of the species to curly top and virus yellows have not been determined.

Patellares

This section forms a very clearly defined group characterized by its viny growth habit and single-germed, nut-like seeds. It may prove an extremely valuable source of desirable genes for beet improvement since none of the species of this section shows spots when exposed to heavy Cercospora infection, and these species have not shown signs of curly top when inoculated by means of viruliferous beet leaf hoppers. *B. patellaris* is susceptible to virus yellows, as was pointed out to me in the Netherlands by H. Rietberg and J. A. Hijner. Abundant seed of *B. patellaris* should be available in 1954.

Studies of the Beta collections of various herbaria in the United States showed that this species (campanulate seed type) had been introduced in the United States with rock ballast from ships probably some time before 1870. The species apparently established itself and spread to a slight extent

from the points of introduction. Isaac Burk, a Philadelphia botanist, collected it in October, 1872, and in 1874 at Kaighns Point near Camden, New Jersey, and across the Delaware River at Girard Point, near Philadelphia, Pennsylvania. Burk reported the collection as "Tetragonia sp." in 1877 (2). Isaac C. Martindale also collected it near Camden in September, 1879. Attempts by the writer to find the plant in 1953 at the places of the old collections were unsuccessful, too many changes having taken place in the wharf area along the Delaware River.

B. procumbens Chr. Sm. and *B. webbiana* Moq. are interesting species. They are very restricted in their distribution and very distinctive in appearance. They have been grown in close proximity in greenhouses since 1925, and no intergrades or indications of hybridization have been observed, nor has there been any indication of hybridization with *B. patellaris*.

Summary

An arrangement of 13 species of the genus Beta into four major groups is suggested. Three of the sections, Vulgares, Corollinae, and Patellares, were originally proposed by Transchel. The fourth group, Nanae, was proposed by Ulbrich for the alpine form, *Beta nana*. This arrangement seems to put related species together and conforms well with the distribution areas of the species. Brief comment is given concerning the individual species.

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Viable Hybrids from Matings of Chard with Beta Procumbens and B. Webbiana[1]

JOHN O. GASKILL[2]

The three viny species of *Beta*—*B. patellaris* Moq., *B. procumbens* Chr. Sm., and *B. webbiana* Moq. (Figure 1)—possess certain very desirable characters which are not known to occur in the sugar beet, *B. vulgaris* L. (1, 2)[3]. Attemps to transfer these characters to sugar beet have failed consistently, the F_1 hybrids ordinarily dying while very small seedlings. Stewart reported obtaining a single F_1 plant—sugar beet x *B. procumbens*—which produced fairly vigorous growth and from which the first and second backcross generations were obtained, the sugar beet serving as the recurring parent (2). However, the plants of the second backcross generation died while relatively small, without producing seed, bringing the series to a disappointing end.

At Fort Collins, Colorado, in 1945, chard (sometimes designated as *B. vulgaris* var. cicla (L.) Moq.) was included in a series of matings between *B. vulgaris* and the three species of the section *Patellares* in the hope that it would be more compatible with the wild material than sugar beet had proved to be. A single flowering plant of the chard variety, Fordhook Giant, was pollinated liberally with a mixture of pollen from the three wild species. Three individual sugar beet plants were similarly pollinated. Seed harvested from the chard plant and from each of the sugar beets produced abundant F_1 seedlings which were distinctly different from the chard and sugar beet selfs.

As usual, none of the hybrids having sugar beet as a parent survived beyond the early seedling stage. However, a small percentage of those from the chard cross did survive and eventually grew to a height of several feet. Young F_1 seedlings representative of the outcome of the four hybridizations are depicted in Figure 2. Chard hybrids at a later stage are shown in Figure 3. All of the chard hybrids appeared to be pollen sterile, but several produced seeds, similar to those described by Stewart (2), following pollination by *B. vulgaris*. Several seedlings representing the first backcross were obtained from those seeds. In general they were extrmely weak, most of them died while very small, and no concrete results were obtained.

Although the 1945 trial failed to produce tangible results, it stimulated interest in this approach to the problem. Subsequently, attempts were made to repeat the process, using *B. patellaris*, alone, as the pollinator. Chard material used as the ♀ included plants thought to be tetraploid as well as the ordinary diploid type. All these attempts failed to produce healthy F_1 hybrids.

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[1] Report of a study made by the Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture, in cooperation with the Botany and Plant Pathology Section, Colorado Agricultural Experiment Station. This paper has been approved for publication by the Station Director as Scientific Series Article No. 441.

[2] Plant Pathologist, Field Crops Research Branch, Agricultural Reserch Service, U. S. Department of Agriculture, Fort Collins, Colorado. Acknowledgment is made to G. H. Coons, Principal Pathologist, and to Dewey Stewart, Senior Agronomist, for seed of wild species used in these investigations, and to J. A. Elder and L. W. Lawson, Agricultural Aids, for assistance in conducting the experimental work.

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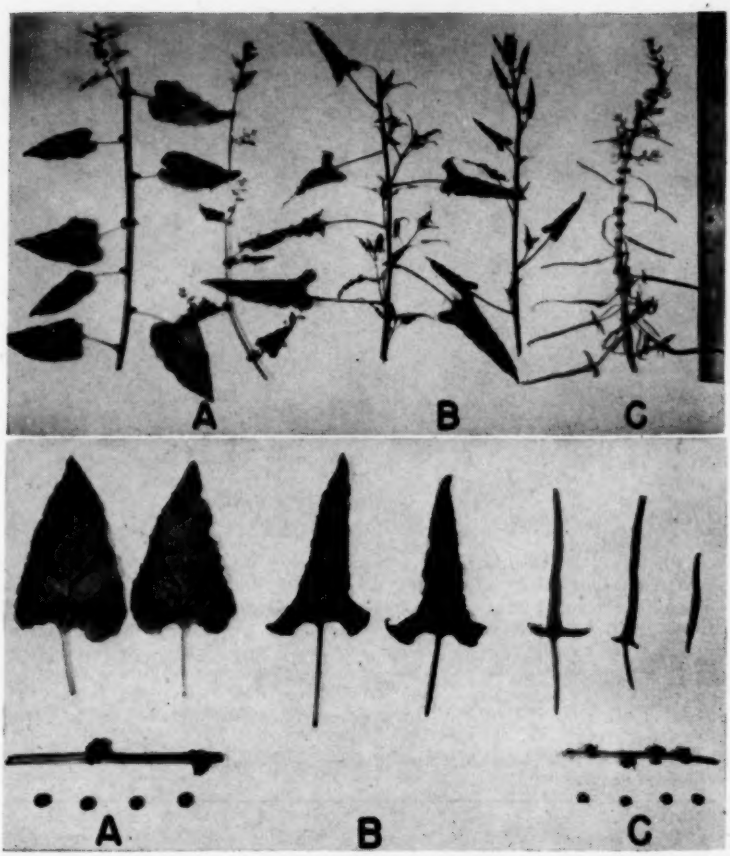

Figure 1.—Species comprising the section *Patellares*—leaves, seeds, and parts of stems: (A) *B. patellaris*, (B) *B. procumbens*, and (C) *B. webbiana*. Seeds of *B. procumbens*, not available when picture was taken, typically are similar to those of *B. webbiana*. Seeds of all three species are hard-walled and monogerm.

In the spring of 1953 eight matings of chard with *B. procumbens* and fifteen matings with *B. webbiana* were attempted. The same variety of chard was used as in 1945. For each mating, branches of a single chard plant and branches of one or more plants of one of the wild species were enclosed in a bag and allowed to interpollinate. The seed lots harvested from the respective chard individuals were planted in the greenhouse on August 19, 1953. Seedling emergence was practically complete by September 2, and counts made on that date (Table 1) showed that F_1 plants had been obtained from 21 of the 23 attempted matings, the total number amounting to approximately 1,035.

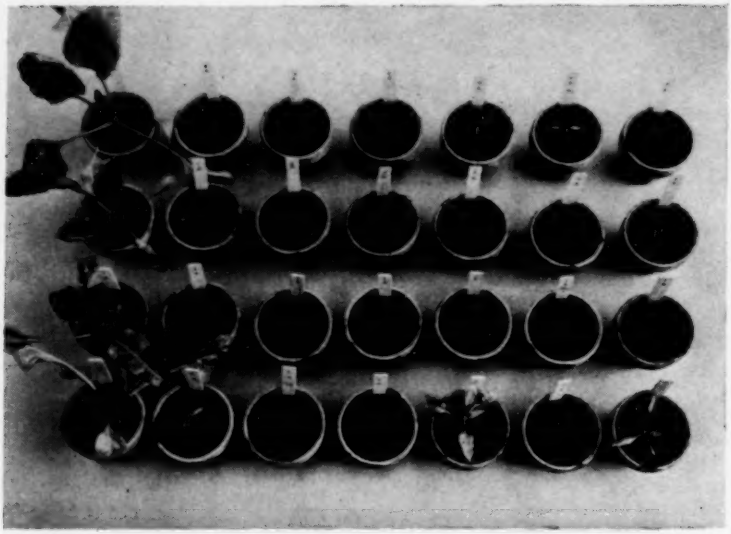

Figure 2.—F_1 seedlings from four crosses, *B. vulgaris* ♀ x species of the section *Patellares*. The upper three rows represent, respectively, three crosses having sugar beet as the ♀ parent. A sugar beet plant occurs at the left in each of those rows. The bottom row represents hybrids having chard as the ♀ parent; chard plant shown at left. The picture was taken November 29, 1945, 2 months after planting. The pots originally contained one plant each, but many of the hybrids had died before the picture was taken. Note that the only hybrids showing promise of survival are from the chard cross.

Table 1.—F_1 Hybrids Obtained from 23 Attempted Matings of Chard with 2 Species of the Section *Patellares*.[1]

	Chard ♀ x *B. procumbens*	Chard ♀ x *B. webbiana*	Total
Total No. of crosses attempted	8	15	23
F_1 seedlings emerged on or before 9/2/53:			
No. of crosses	7	14	21
No. of plants (approx.)	445	590	1,035
Healthy appearing F_1 seedlings at least 6 inches high, 1/18/54:			
No. of crosses	3	2	5
Total No. of plants	6	19	25
No. of plants flowering	1	5	6

[1] Data obtained from a partial planting of seed, August 19, 1953.

The hybrids were readily distinguishable from the chard selfs, which were discarded. As in the 1945 trial, most of the F_1 seedlings were unthrifty and died early. A small percentage of those obtained from several matings survived the lethal stage and appeared quite healthy 5 months after planting (Table 1 and Figure 4). Considerable variation was observed both in vigor and in foliage type, among these plants—even among those having

the same species as the ♂ parent. As indicated in Figures 1 and 4 the hybrids were distinctly different from either parent but tended to resemble the wild type more closely. The few which were flowering on January 18, 1954, appeared to be pollen sterile. It is interesting to note the similarity between these hybrids (Figure 4) and those obtained from the 1945 trial (Figure 3). This observation and the failure to obtain viable hybrids when *B. patellaris* was used as the only source of wild pollen indicate that this species was not a parent of any of the healthy hybrids obtained in 1945.

Figure 3.—F_1 hybrids, chard ♀ x the section *Patellares*, February 26, 1946, five months after planting. The specimen at the left was approximately 2 feet high when the picture was taken; the others were about 6 inches high.

The counts made on January 18, 1954, (Table 1) show a total of 25 F_1 plants, at least 6 inches high, classed as healthy on that date. Three different matings of chard x *B. procumbens* and two of chard x *B. webbiana* were represented among those 25 plants. Sixteen of the twenty-five were more than 1 foot high and six were flowering.

Many problems must be solved if desirable characters of the section *Patellares* are to be utilized for genetic improvement of the sugar beet. In the past the first problem—the lethal condition of the F_1 seedlings—has essentially precluded research on all others. The results reported in this paper apparently offer a means of bypassing the first serious obstacle, thus opening the way for vigorous attack on some of the others. Chard is closely related to sugar beet, crosses readily with it, and the hybrids are vigorous and fertile. Consequently, if desirable genes could be transferred successfully from the section *Patellares* to chard, presumably those genes then could be passed on to sugar beet.

Summary

Successful outcome of hybridization in 1945 and again in 1953, between chard as female parent and *Beta procumbens* and *B. webbiana* as

Figure 4.—A chard plant, at left, and F_1 hybrids representing four different matings, chard ♀ x species of the section *Patellares*. The two hybrids at the right are chard x *B. procumbens;* the other two are chard x *B. webbiana*. The picture was taken January 15, 1954, approximately 5 months after planting.

pollen sources, is reported. In the more recent work, a total of 23 attempted matings gave rise to approximately 445 and 590 F_1 plants from *B. procumbens* and *B. webbiana*, respectively. Six plants of the first group and 19 of the second were classed as healthy in January, 1954, at the age of 5 months. One plant of chard x *B. procumbens* and 5 of chard x *B. webbiana* were in flower at that time. Hybridizations with chard may afford a technique for transfer of genes from these wild species to sugar beet.

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NOTE—Soon after the above article had been prepared, the roots of seedlings which had been grown for three months in soil infested with sugar beet nematode (*Heterodera schachtii* Schmidt) were washed and examined microscopically. Specimens of the female nematode were found on 29 or 30 sugar beet plants examined and on all of the 7 chard plants in the test, but were not found on any of the F_1 hybrids—chard x *B. procumbens* (2 plants) and chard x *B. webbiana* (4 plants). Most of the hybrids were small, and the results cannot be considered as conclusive, but they do suggest that the high degree of nematode resistance, known to be a characteristic of the 2 wild species, was transmitted to the hybrids.

Viable Interspecific Hybrids Between Wild Species In the Section Vulgares and Species in the Section Patellares in the Genus Beta

R. K. OLDEMEYER[1]

The species in the section *Patellares* Transch. (2)[2] of the genus *Beta*[3] possess several characters of great economic importance if they could be incorporated into sugar beet varieties. The species of this section, *B. patellaris, B. procumbens* and *B. webbiana,* are all single germ, and highly resistant, if not immune, to sugar beet nematode, *Cercospora* leaf spot and curly top virus (1). All attempts to hybridize these species with the sugar beet have ended in failure with one exception because of the inviability of the F_1 hybrid seedling. Stewart (1) has discussed the problem of the inviability of sugar beet x *Patellares* hybrids fully and described one viable hybrid which was lost in subsequent generations.

This investigation was initiated to determine whether viable hybrids could be obtained between species in *Patellares* and wild forms of the section *Vulgares* Transch. which are cross compatible with sugar beet. If such hybrids could be produced, perhaps the transfer of the valuable germ plasm from the *Patellares* could be accomplished by crossing the hybrid with sugar beets. The possible use of bridge hybrids for the transfer of *Patellares* germ plasm to sugar beets is not a new idea. Gaskill[4] obtained a viable Swiss chard x *Patellares* hybrid in 1945, but its descendants were lost in succeeding generations.

Materials and Methods

The material from the section *Vulgares* used in hybridization included two accessions of *B. macrocarpa,* three of *B. maritima,* one of *B. atriplicifolia* and one of a tetraploid sugar beet. One accession of *B. webbiana,* two of *B. procumbens* and two of *B. patellaris* were included in the *Patellares* material used. The parental material was obtained from the U. S. Department of Agriculture with the exception of two accessions of *B. maritima*—one from Israel, and one from the Imperial Valley in California—and the tetraploid Kleinwanzleben sugar beet from Germany.

Plants from the section *Vulgares* were used as pistillate parents and from the section *Patellares* as staminate parents in all matings. Crosses involved nearly all *Vulgares* accessions with all *Patellares* accessions.

All the *Vulgares* accessions were considered to be diploid (2n = 18) with the exception of the tetraploid sugar beet (2n = 36). Recent investigation by Helen Savitsky[5] indicates that *B. webbiana* and *B. procumbens* are diploid (2n = 18) and *B. patellaris* is tetraploid (2n = 36).

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[1] Plant Breeder, Agricultural Experiment Station, The Great Western Sugar Company, Longmont, Colorado.

[2] Numbers in parentheses refer to literature cited.

[3] Coons, G. H., has chosen to call this section *Procumbentes* Ulbrich. Proc. Amer. Soc. Sugar Beet Tech., 1938, 74-76.

[4] Gaskill, John O., personal communication.

[5] Unpublished data. Collaborator, Division of Sugar Plant Investigations, U. S. Department of Agriculture in cooperation with the Beet Sugar Development Foundation, Salt Lake City, Utah.

Eight to ten flowers from each of the branches of plants to be used as pistillate parents were emasculated prior to anthesis by rolling the immature anthers from the bud with a sharp instrument. The branches with their emasculated flowers, after being washed with water, were enclosed in a small paper bag to prevent unwanted pollination. At the time the bracts of the flowers opened and the stigmas had become enlarged, pollen collected from several plants of a species in *Patellares* was applied to the stigma of the emasculated flowers with a clean camel's hair brush. At least one and in many cases five or six crosses were made for each mating.

The mature seed was scarified by shaving the pericarp of the seed with a razor blade until the germ was exposed. The seed was then germinated in a germination cabinet and transplanted to pots as it sprouted.

Results

No seeds were obtained from matings involving *B. patellaris* except when it was mated with tetraploid sugar beet. Only inviable hybrids grew from these seeds, however. Matings involving one accession of *B. maritima* and one accession of *B. macrocarpa* with *Patellares* species produced no viable seeds. The crosses of tetraploid sugar beet x *B. procumbens* and *B. webbiana* also resulted in no viable seed.

Eight relatively viable hybrids were obtained.

No. of Hybrid Plants	Mating
3	*B. macrocarpa* x *B. webbiana*
2	*B. macrocarpa* x *B. procumbens*
1	California dwarf wild (*B. maritima*) x *B. procumbens*
1	*B. atriplicifolia* x *B. procumbens*
1	*B. atriplicifolia* x *B. webbiana*

In addition to the viable hybrid plants produced from the above matings, other hybrid plants which died before secondary branching occurred, as described by Stewart (1), were produced from the same matings.

One hybrid plant from the mating, *B. macrocarpa* x *B. webbiana*, was extremely vigorous (Figure 1). The growth habit of this plant was intermediate between the parents. The flowers were borne in clusters of three or four similar to *B. macrocarpa*. Nearly all the stamens were vestigial, being composed of a filament only and rarely bearing anther sacs which when present were devoid of pollen. The embryo sacs of all flowers examined were brown and necrotic at the time of flowering. The stigmas appeared normal. No flowers showed ovary stimulation when the plant was exposed to sugar beet pollen.

Another hybrid which flowered from the mating California dwarf (*B. maritima*) x *B. procumbens* had normal stamens but the anther sacs were devoid of pollen. The embryo sac appeared normal at the time of flowering. This plant died from root rot shortly after it began flowering.

Another hybrid, *B. atriplicifolia* x *B. procumbens*, will flower; there is little chance that the other hybrids, listed above, will flower although they continue to grow slowly (Figure 2).

Figure 1.—Extremely vigorous *B. macrocarpa* x *B. webbiana* hybrid growing in a 12-inch pot.

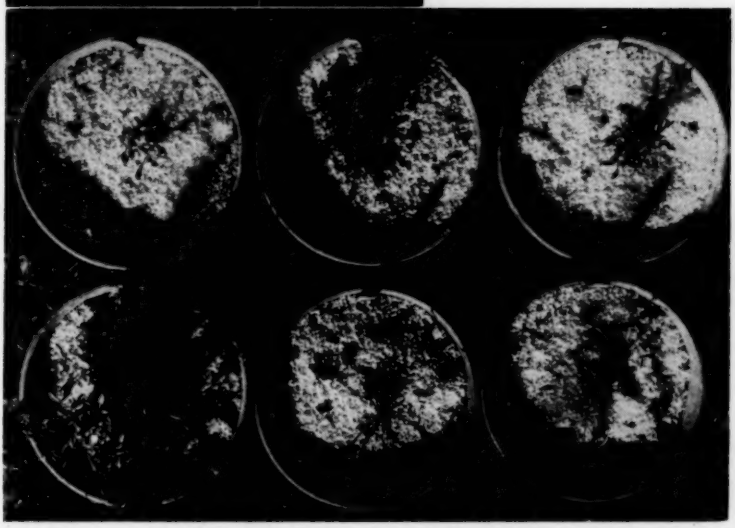

Figure 2.—Six-month-old *Vulgares* x *Patellares* hybrids in 8-inch pots. Top, left to right, *B. atriplicifolia* x *B. procumbens*, *B. atriplicifolia* x *B. webbiana* and *B. macrocarpa* x *B. webbiana*. Bottom, three *B. macrocarpa* x *B. procumbens* hybrids.

Discussion and Conclusions

Viable hybrids of some strains of some species in the section *Vulgares* with *B. webbiana* and *B. procumbens* in the section *Patellares* can be produced. The production of fertile progeny from the mating of such hybrids with the sugar beet is the next step in the transfer of valuable characters from *Patellares* to sugar beet. It should be possible to develop basic breeding material having the desirable characters from *Patellares* following the segregation and recombination of genes in the progeny of such hybrids crossed to sugar beet.

The production of bridge hybrids should be confined to diploid ($2n = 18$) species inasmuch as the introduction of triploidy sterility would only add to the sterility problem already present due to interspecific crosses.

Summary

Matings of some strains of several species in the section *Vulgares* with species in the section *Patellares* were made. A failure of some matings resulted from embryo abortion, lack of fertilization and inviability of the F_1 hybrid seedling. Viable hybrid plants resulted from the matings of *B. procumbens* and *B. webbiana* with *B. atriplicifolia*, California dwarf wild (*B. maritima*) and one accession of *B. macrocarpa*.

One hybrid plant, *B. macrocarpa* x *B. webbiana*, was extremely vigorous. Its growth habit was intermediate between the parents, but the flowers were borne in groups of three, four, or five, similar to *B. macrocarpa*. The flowers of this plant were not functional. Another hybrid plant, California dwarf wild x *B. procumbens*, died shortly after it began flowering. A *B. atriplicifolia* x *B. procumbens* hybrid will flower; others will probably die before flowering.

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A Grafting Technique Enabling an Unthrifty Interspecific Hybrid of Beta to Survive

GERALD E. COE[1]

F_1 seedlings arising from crosses of sugar beets, *Beta vulgaris* L., with each of the three species, *Beta procumbens* Chr. Sm., *B. patellaris* Moq., and *B. webbiana* Moq., do not survive beyond the seedling stage. Stewart (2)[2] obtained several hundred of the hybrid seedlings but was able to grown only a single plant, *B. vulgaris* X *B. procumbens,* to maturity.

There is interest among sugar beet breeders in making inter-specific hybrids with these wild species, since these species appear to be immune

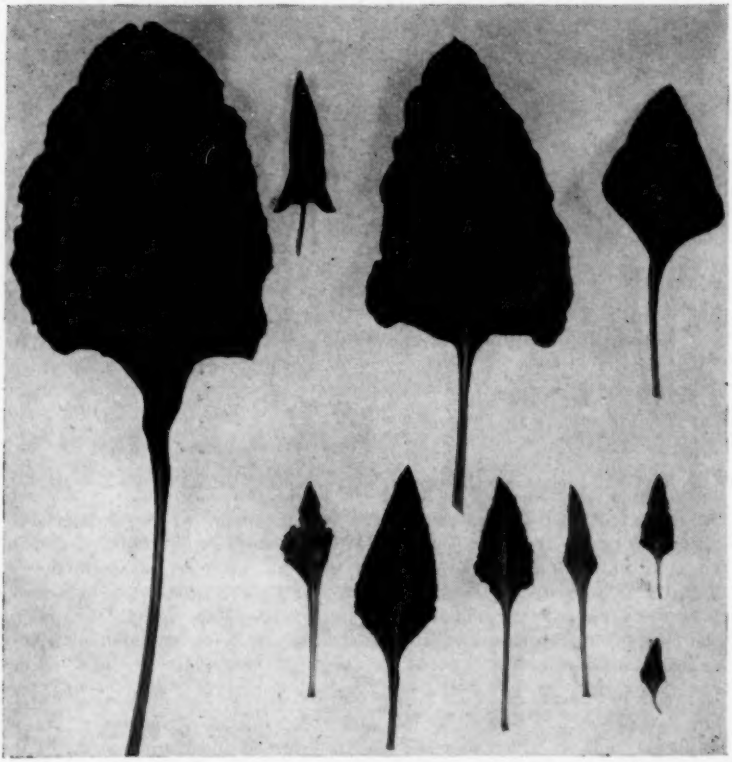

Figure 1.—Comparisons of leaves of sugar beet, *Beta procumbens,* and their hybrid. The two leaves at the upper left are sugar beet and *B. procumbens,* respectively. The others are from the interspecies hybrid.

[1] Geneticist, Field Crops Research Branch, Agricultural Research Service, United States Department of Agriculture.

[2] Numbers in parentheses refer to literature cited.

Figure 2.—Hybrids of sugar beet X *Beta procumbens*. The graft union of the plant on right can be seen just above the soil level.

to leaf spot and show high resistance to curly top, two of the major diseases of sugar beets in the United States. It has been reported that the sugar beet nematode, *Heterodera schachtii* Schmidt, cannot complete all stages of development in the roots of these wild species (1). If these factors for disease resistance and nematode reaction can be transferred to the sugar beet, they may contribute to sugar beet improvement. An effective means of growing the unthrifty F_1 plants to sexual maturity would be helpful.

It was observed that the F_1 seedlings do not form a secondary root system. Under conditions of good culture the hypocotyl, cotyledons and young leaves may remain alive for several weeks, but the primary root system fails to expand, turns dark and finally becomes necrotic. Sugar beet seedlings growing in the same progeny with the interspecific hybrids and in the same environment make excellent growth. The obvious deduction is that if the unthrifty F_1 seedlings were given more effective root systems to support growth, they might have a chance of surviving. A grafting technique to accomplish this with a *Beta vulgaris* X *B. procumbens* hybrid has been developed.

Sugar beet seedlings 2 or 3 days old are used as the stock of the graft. The hybrid seedling is used as the cion when initials of its first leaves are visible. A hole in which to make the insertion of the cion is made in the apex of the stock seedling with a small dissecting needle and then enlarged with a larger one. A sloping cut is made through the hypocotyl of the hybrid no more than ¼ inch below the point of attachment of the cotyledons. The cut end of the cion is inserted into the opening in the stock, and the grafted plant is placed in a high humidity chamber until the cion has grown about 2 inches. It can then be taken from the high humidity

Figure 3.—Hybrids of sugar beet X *Beta procumbens*. The plant on the left has numerous branches started.

chamber. The most important factor influencing the success of the union appears to be the use of seedlings of the proper age, i.e., a very young sugar beet seedling for the stock and an older hybrid seedling for the cion. It also appears important to use, as stocks, seedlings which are closely related to the sugar beet parent of the F_1 hybrids. The greatest difficulty encountered is the mechanical dislodging of the cion by growth of leaves from the apex of the stock.

Only 25 of the grafts with F_1 plants of sugar beet X *B. procumbens*, or 7 percent of those attempted, have given successful union. Of the 25 hybrid cions, 15 have grown to be vigorous individuals. No two of the 25 plants have been alike in appearance. They have shown great morphological variations, particularly in leaf size and leaf shape (Figure 1). The amount of branching and the extent of stem development have also shown

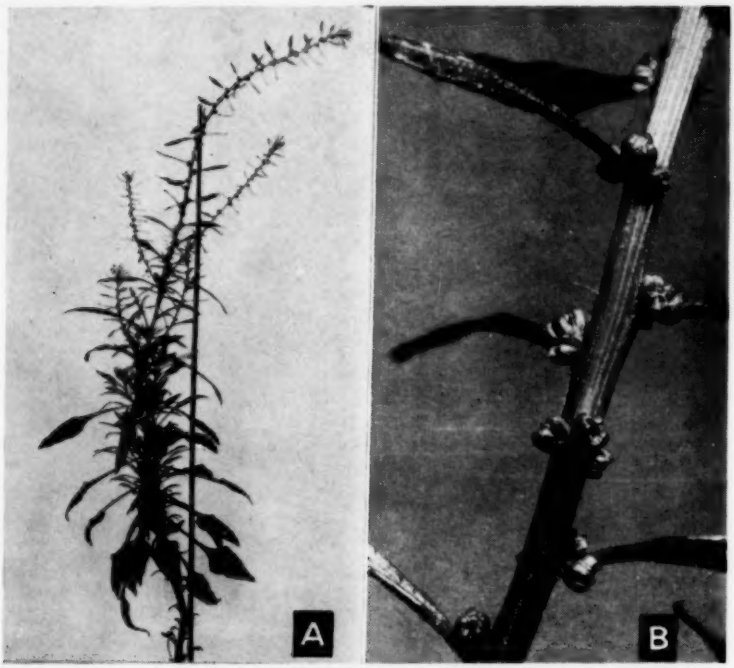

Figure 4.—Left (A), inflorescence of species hybrid, sugar beet X *B. procumbens*. Right (B), flowers of species hybrid, sugar beet X *B. procumbens*. These flowers closely resemble those of sugar beets.

considerable variation (Figures 2 and 3). The inflorescences and flowers have resembled more nearly those of the sugar beet than those of *B. procumbens* (Figure 4). The morphological variations are encouraging since they are indicative of genetic differences within the wild species which should broaden the combining possibilities in future breeding work. Some successful combinations may eventually be found.

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Time-Saving Techniques and Increased Accuracy Using the Punched Card System in Experimental Work[1]

G. J. Hogaboam[2]

Introduction

A bibliography of the important papers concerning the use of the punched card system in science, statistics and education was published in 1950 (5)[3]. Most of these papers, however, were written before the punched card calculators were introduced. These machines greatly simplify such operations as multiplication and division. Armstrong (1) gives a good description of capabilities of present available punched card equipment as well as an estimate of their monthly rental rates.

It is the purpose of this paper to point out some additional advantages to be gained by using the punched card machine from start to finish of an experiment.

Discussion

As soon as the design of an experiment is decided upon the cards for the experiment can be punched and verified for accuracy. One card is punched for each plot. This card should contain all the identifying information that is to be entered in the field book concerning the plot as well as all sorting information needed for the analysis.

By punching the plot cards at this time, these cards may be used by the tabulating machine to print the field book and packet labels. Various sizes and types of paper are available on which to print the field book. The cards may be sorted to any desired field arrangement before printing the field book. After the field book is printed the pages may be separated, the edges trimmed, and bound into a semipermanent or permanent book. Whenever gummed paper labels can be employed for seed packet or treatment identification, these labels may be machine-printed to contain any of the following information: entry or treatment number, plot number, and identification of seed or treatment (may be expressed as numbers, letters or a combination of both).

By handling the early phases of any sizable experiment in this manner the experimenter can expect to save approximately 80 percent of the time required to prepare the field book and packet labels. This method also practically eliminates any chance for transcribing errors since the printing of all information is machine-copied from a single set of cards. Furthermore, with a machine-printed field book, it is unnecessary to rearrange the data before presenting the book to the punched card operator for transcription and verification onto the respective punched cards.

Frey, Rossman and Taschner (2) point out the value of prepunching several experimental designs on master cards. With such a set of master

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[1] Cooperative investigations of the Field Crops Branch, Agricultural Research Service, U. S. Department of Agriculture, and the Michigan Agricultural Experiment Station (Journal Article 1,613 of Michigan Station).

[2] Research Agronomist, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture, East Lansing, Michigan.

[3] Numbers in parentheses refer to literature cited.

cards at hand, the cards may be cut for a new experiment and the field book and packet labels printed in a matter of a few hours. Another advantage gained by the punched card system is the ability to get a quick summary of data during the growing season, if needed.

To get an idea of the saving of time and money in analyzing experiments by the punched card system, a study was made of a series of analyses. Seventeen experiments were analyzed by IBM machines. These were made up of nine 8x8 Latin squares, one 8x6 random block, five 12x8 random blocks and two 12x6 random blocks. Each of these experiments was analyzed for five separate classifications except for two experiments which were analyzed for only one classification. A total of 77 separate analyses were taken as far as SS Net for the total, all variables and remainder. It was found that the completed IBM analysis cost only one-third as much as the conventional method in both time and money. It should be pointed out, however, that these calculations were made on IBM machines rented and operated by Michigan State College and no charges are included for overhead expenses or profit. Ryser (6) reported greater accuracy and a large saving of time by the IBM method even when the analyses were taken only as far as all total sums needed in the analyses.

Perhaps the most difficult part of the punched card system is knowing how to set up the problem for the machine operators and explain it in such a way that they will understand what is needed. One of our prepunched 8x8 Latin square designs is shown below with a copy of the instructions given to the IBM operator for all operations including its analysis.

Instructions to Set up Experiment

Table 1.—The Design: Experiment Number 1 by Entry Number.

Col.	1	2	3	4	5	6	7	8
Row								
8	7	8	3	1	6	4	2	5
7	2	3	6	4	1	7	5	8
6	4	5	8	6	3	1	7	2
5	6	7	2	8	5	3	1	4
4	8	1	4	2	7	5	3	6
3	5	6	1	7	4	2	8	3
2	1	2	5	3	8	6	4	7
1	3	4	7	5	2	8	6	1

Punch the year "53" in all cards. Copy the plot numbers and entry numbers onto the cards from "The Design: By Field Book Arrangement." (Table 2). Check the transcription on the verifier. On the sorter and card counter check to see that there are: eight cards for each row (IBM col. 5), eight cards for each column (IBM col. 6), and eight cards in each entry number (IBM col. 7). Report any discrepancies. Arrange the cards in order of increasing plot numbers and print an original and the desired number of carbon copies of the field book. Leave a two-inch margin on top for binding and a two-inch margin on the left for seed lot identification. Print 32 plots on a page. Leave two spaces between the plot number and the entry number so these are readily distinguishable.

Table 2.—The Design: By Field Book Arrangement.

Seed Lot	Plot Number[1]	Entry Number
	(3-4) (5) (6)	(7)[2]
	1 1 1	3
	1 1 2	4
	1 1 3	7
	1 1 4	5
	1 1 5	2
	1 1 6	8
	1 1 7	6
	1 1 8	1
	1 2 1	1
	1 2 2	2
	etc.	
	1 8 7	2
	1 8 8	5

[1] The plot number is a combination of experiment number, row number, and column number in that order from left to right.
[2] Numbers separated by parentheses indicate column numbers on IBM card.

Table 3.—IBM Card Setup.

IBM Column	Item
1-2	Year
3-4	Experiment number) plot
5	Row number) number
6	Column number)
7	Entry number
10-14	Beets per acre
15-19	Tons per acre
20-23	Percent sucrose
24-27	Percent purity
28-32	Pounds sucrose per acre
33-35	Number beets per plot
36-38	Weight per plot
39-42	Factor for beets per acre
43-47	Factor for tons per acre

Note: IBM columns 8-9 left vacant intentionally so that data in subsequent columns will correspond to similar items in IBM card set up for 12x8 designs.

Instructions to Analyze Data

Transcribe the data from the field book onto the appropriate IBM cards according to previous instructions on IBM card set up (Table 3). Check the transcriptions for accuracy on the verifier.

Instructions for converting plot data to a per acre basis:

I. Number of beets per acre (10-14)[4].

Multiply number of beets per plot (33-35) by the factor for number of beets per acre (39-42). One factor for each experiment. Round answer to nearest whole number and punch in Col. (10-14). Example: In experiment one located at the Ballinger Farm, plot number 111 contained 204 beets. The factor for number of beets per acre in this experiment is 97.24. 204 x 97.24 = 19,836.96, record as 19,837.

II. Tons of beets per acre (15-19).

Weight per plot (36-38) x factor for tons of beets per acre (43-47) and round the answer to three places to the right of the decimal point. Example: In experiment one located at the Ballinger Farm, the weight of plot 111 was 176 lbs. and the factor is .04862. 176 x .04862 = 8.55712, record as 08.557.

III. Pounds of sucrose per acre (28-32).

Multiply tons of beets per acre (15-19) by the percent sucrose (20-23) and multiply that answer by 2,000 in all cases. Round answer to the nearest pound. Record in Col. (28-32). Example: Experiment one, plot 111, Col. (15-19) = 08.557, col. (20-23) = 20.70 percent. 8.557 x .2070 x 2000 = 3542.5980000, record as 3543 in col. (28-32).

ANALYSIS: Analyze each experiment for the following classifications: number of beets per acre (10-14), tons of beets per acre (15-19), percent sucrose (20-23), percent purity (24-27), and pounds of sucrose per acre (28-32). For each analysis of each experiment:

[4] Numbers in parentheses in "Instructions to Analyze Data" indicate IBM columns.

1. Square each master card (plot card) and list the grand sum, grand sum of squares and grand card count.

2. Make summary cards for the following sortings (controlled variable):

Table 4.

Sortings	IBM Column	Number of summary cards needed
Row	5	8
Column	6	8
Entry Number	7	8

Put totals on each summary card.

3. Square totals on each summary card and list for each sorting: the sum, the sum squared, and card count for each summary card; the grand sum, the grand sum of squares, and the grand card count.

4. Determine CT (Correction Term) for each analysis by squaring the grand sum for the experiment (obtained in instruction 1) and dividing by the grand card count (obtained in instruction 1).

5. Divide the grand sum of squares (obtained in instruction 3) by the card count listed by individual summary cards. Determine this for each sorting, viz., by rows, by columns, and by entry number.

6. Subtract the CT (obtained in instruction 4) from (a): each answer obtained in instruction 5, and (b): from the grand sum of squares of individual plots (obtained in instruction 1).

7. From the value obtained in 6 (b) subtract all the values obtained in 6 (a) (by rows, by columns, and by entry number). This answer is the remainder.

8. List items in the order indicated below:

Grand sum of squares	Answer obtained in 6 (b)
Row	Answer obtained in 6 (a)
Columns	Answer obtained in 6 (a)
Entry number	Answer obtained in 6 (a)
Remainder	Answer obtained in 7
CT	Answer obtained in 4

9. Arrange the individual plot cards by entry number and list: plot number, entry number, pounds of sucrose per acre, tons per acre, percent sucrose, percent purity, and number of beets per acre. Give sub-totals by entry number and grand totals by experiment number.

Discussion

The accuracy of the calculations may be checked by comparing all grand totals for each analysis, by checking card counts for discrepancies, and by checking the reasonableness of the figures in the net sums of squares column (obtained in instruction 8). The final listing by entry number should also be checked for reasonableness.

The analysis of a randomized block is very similar to the preceding example of a Latin square analysis. Homeyer, Clem and Federer (4) give detailed instructions for the analysis of most types of lattice designs by

the punched card method. However, this article was written before the punched card calculators were in operation, hence their procedure can be somewhat simplified. Split plot designs are also well adapted to the punched card machine method of analysis. The author has conducted 20 analyses of a split-split-split plot design, containing 384 plots, on the IBM machines. This experiment (3) could not have been handled in such detail had the IBM machines not been available.

Summary

While appreciable savings of time and money have resulted from the punched card analysis of data, further savings may be realized through preparations of field books and gummed labels with the punched card machine. Also, fewer chances for human error occur by the extended use of the punched card machine method.

ACKNOWLEDGMENT

Acknowledgment is made to Norma Taschner, Tabulating Service, Michigan State College, for help in connection with the IBM equipment and its capabilities.

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Methods of Sugar Beet Selection in the U.S.S.R.

A. Archimowitsch[1]

Selective breeding of sugar beets in Imperial Russia was very well developed. At the end of the eighties and in the beginning of the nineties certain firms had introduced individual selection. The size of the parent stock selected increased every year. At the beginning of the first World War, almost two thousand pedigree varieties were selected annually at the several breeding stations. For evaluation of the quality of the generations, complex methods of mathematical analysis of test data were used. In making up the seed for commercial release, crosses from carefully studied families were used (16)[2].

During the revolution of 1917 most of the breeding stations were destroyed. Reconstruction of some of them began in 1919. In 1920 the Sakharotrest (Sugar Trust) set up the office of varietal breeding and seed production management for the purpose of directing their activities. The first steps in selective breeding in Soviet Russia were carried out under very difficult conditions because the breeding stations and laboratories had been ruined, the seed stocks mixed up, the breeding records destroyed. To this should be added that many Polish breeders, to save their lives, had moved to Poland during the revolution.

Mass Selection

During the early years of activity of the Soviet Breeding Stations, mass selection was generally used.

During the winter of 1921-22, more than one million roots were analyzed at 12 breeding stations of Sakharotrest (Sugar Trust).

As regards the makeup of the seed released by factories for commercial planting, Soviet selections had received a sudden setback by several dozen years except for the fact that the original stock for Soviet breeding was not accidental material, as was the case in the early years of selective breeding of sugar beets in Imperial Russia, but consisted of varieties which were the result of long selection during the pre-revolutionary period. The products of mass selection were propagated once and the seed obtained was then released to the factories. This method was in use until 1925.

During the years 1925 to 1931, the practice was to propagate for commercial release without selection the best numbers of elite varieties from breeding stations, i.e., numbers which had received high rating in varietal tests. After 1930 this method was gradually replaced by a new one which involved the growing of several elite strains from breeding stations which had been given good ratings in varietal tests. Whenever a lot of seed was released it was compounded in such a way that in the next generation cross pollination would take place. This method enables the breeder to study combinations which manifest the effects of heterosis, in order that he may produce such combinations at will. However, Soviet literature contains no references pointing to the finding of such combinations.

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[2] Numbers in parentheses refer to literature cited.

Early in the history of Soviet selective breeding, mass selection was used by experienced men (Sempolovsky, Lebedinsky, Hellmer, Goodwill); this method was of positive value because it preserved the basic nucleus of breeding material in the possession of the breeding stations. In contrast to this, young scientists in charge of other breeding stations were carried away by methods of analytical selections which resulted in excessive splitting of the original materials of the station without retaining the original core. Most of the varieties released by stations Uladovka, Ivanovka, Ramon and Lgov were the result of mass and group selection.

Individual Selection

Soon after the reactivation of breeding stations, some of them began to change over to individual selection. In 1923 there were approximately 2,500 strains which were being studied at all breeding stations.

The methods of selection used at that time have been described in the publications by B. Lebedinsky (6) and I. Voitkevich (15), and also in a special volume devoted to a description of breeding stations (14).

The number of selected parents continued to grow and, in 1938, 7,765 numbers were planted out at all the breeding stations in varietal breeding tests (3). The parents selected each year are planted out in groups for seed production. In selecting the groups, the origin of the parent stock or the direction of selection is used to guide the breeder in his choice. Since only a small quantity of seed is obtained from each parent, great care is given to preliminary vegetative propagation—the dividing of roots in order to obtain clones by the method of Nowoszek.

In this method the clones are also set out in groups for cross pollination. The amount of seed obtained by this method from one parent is quite sufficient for making tests of the progeny for two years in succession and for subsequent propagation of the best among the progeny. With this kind of propagation, distance isolation is used. To begin with, individual strains are grown between rows of high-growing plants (southern hemp) at a distance of 5 to 10 meters between groups. In producing subsequent generations the distances between groups are increased to tens or even hundreds of meters; the groups are placed between plantings of field crops. In any case, as pointed out by Savitsky (10), beginning with the F_2 generation, propagation takes place within a circle of forms related in their origin and, as a result, there is a gradual decrease in yield of the progeny (regression).

This circumstance was taken into account in making up lots of seed for commercial release by mixing several strains for cross pollination. Beginning with 1927, products of individual selection (7) were among the lots of seed released.

Inbreeding

Inbreeding was initiated at certain breeding stations as soon as self fertile races were discovered. An outstandingly large number of these was found at the Ivanovka breeding station. Subsequent generations were obtained either by the use of selfing (4) or by the method of sister crosses after Munerati (1). In the experiments of Grinko (4), the material was carried to I_6 generation in 1940.

In regard to yield, the products of segregation were predominantly low in tonnage. In regard to sugar the inbred strains segregated into forms which were both high and low in sugar. Selection for increase in sugar content gave positive results (4). The morphological characters (especially shape of the leaves and the leaf rosette) exhibited diverse forms in the first inbred generations, but beginning with I_3 a marked morphological uniformity was observed in the progeny, and in I_4 and I_5 the progeny became practically uniform. A considerable number of cases developed deformities and abnormalities in structure of the leaf lamina, petioles, the flower and the seed balls (1, 4).

On the positive side, some races manifested relative resistance to *Cercospora* (4). The progeny of crosses between inbred lines showed occasional heterosis but these forms did not become of commercial significance. A study of the progeny of self fertile races and of crosses between self fertile and self sterile races showed that the character of self fertility is inherited as dominant (1, 4). Investigations by H. Savitskaya demonstrated that the manifestation of the character of self fertility depends to a great degree on the temperature of the air at the time of flowering (11).

The Hybridization Method of Breeding

To increase the scope of original breeding material for subsequent work in selection, Savitsky carried out a series of crosses between sugar beets and other cultivated beet forms—fodder beet, semi-sugar beet, table beet and mangold. The results of these crosses proved very interesting both in the theoretical and practical sense. The cross of the sugar beet with the wild *Beta vulgaris* L. showed great promise for the purpose of increasing resistance to *Cercospora*. Hybrids of the sugar beet with the green varieties of the mangold and with the wild *Beta vulgaris L.* of northern Europe proved to be very interesting for purposes of further increasing the sugar content. Hybrids from sugar and fodder beets proved to be very promising for further increasing the tonnage of the sugar beet (10).

To prevent uncontrolled hybridization between different materials and also to eliminate the tendency to degeneration caused by crossings of related strains, Savitsky worked out a whole series of crossing methods (diallel, saturation, double crosses) between populations, products of individual selection, inbred lines, clones obtained by continuous vegetative propagation, etc. (10). Shortly before the beginning of the second World War, some of these plans were being realized at the All-Union Institute of the sugar industry and at certain breeding stations. Orlovsky in 1947 (8) reports considerable progress resulting from a method of selection proposed by V. Savitsky after tests of the hybrids.

Control of Pollination

By controlled pollination we understand a system of measures designed so that pollination of previously selected material or material propagated with the use of selection takes place in the desired direction. The first attempts to regulate pollination consisted of certain group arrangements of the elite stock or of lines at the time of their propagation. Before the second World War, the attention of many breeders was aimed at a study

of certain populations, strains and clones to be used as pollinizers for making diallel and other types of crosses. Of no less importance was the need to work out a system of technical methods which would assure pollination in a predetermined direction such as self pollination, pollination between related individuals, crosses in a selected combination, etc.

This includes the study of the role played by wind and insects in the transfer of pollen, the use of present isolators and the construction of new types, a study of methods of crosses inside the isolators and under free-blooming conditions, a study of the effectiveness of distance isolation, etc. There is no need to discuss here the results of research done in this direction because these results have been discussed in sufficient detail in a special summary by the present writer (2).

Special Methods in Sugar Beet Selection

Among the special methods used in sugar beet selection, methods which were or still are in use by Soviet breeders, the following should be noted:

1. Before 1930, many breeders used the indirect method of selection by the morphological characters of leaf rosette and root, for purposes of increasing the percent of sugar and the weight of the root. Numerous calculations were made in order to determine correlations between morphological and utilitarian characters. For selection purposes and for descriptions of populations and progenies, various classifications of shape of root, leaf, leaf rosette and steckling were worked out. This method did not yield any positive results and interest in it has decreased.

2. Selection for vigor during early development. Savitsky proposed that in selection for increased root weight special attention should be paid to the rate of maturing of the developing root. Group selections which he carried out in 1936 have fully confirmed the value of his method (9). Mazlumov (7) at Ramon station also made use of this method and has produced certain varieties at the station with the aid of it. Goodwill (5) at Lgov station has made use of the method of evaluating progenies by rate of growth during the earliest stages of development under laboratory conditions. He finds it practical to discard on this basis about one-third of all the progeny intended for use in tests under field conditions and in this manner to greatly reduce the area to be used for varietal tests.

3. Selection for early maturing is of particular importance for northern regions of beet cultivation because of the short vegetative season (Kursk, Voronezh regions, western Siberia). However, early maturing beet varieties are more important in the Soviet Union than all other regions where beets are grown. This is true because the work of harvesting sugar beets in the USSR takes such an inordinate amount of time that it is not always possible to complete it before the advent of frost. For this reason, sugar beet harvesting begins very early, usually from September 10th on, and therefore the early maturing varieties are found to be very valuable. Certain varieties from the Ramon breeding station (Voronezh district) are especially early in maturing.

4. Selection for resistance to fungus diseases. Among the causal agents of fungus infection of sugar beets which are most wide-spread in USSR are: *Phoma betae* Frank, *Cercospora beticola* Sacc. and *Botrytis cinerea* Pers. No great progress in the work of producing varieties which would be comparatively resistant to these fungi can be noted for the USSR. Among other varieties, those from the Uladovka breeding station are slightly outstanding in their resistance to storage rot (*Botrytis cinerea* Pers.) Phytopathologist V. Shevchenko of Belaya Tzerkov breeding station proposed a method for determining the resistance of individual roots to this infection (13).

5. Selection for decreasing the percent of "harmful nitrogen" content and for increasing the good quality (purity) of beet juice is being carried on at Pervomaiskaya (May First) breeding station in Northern Caucasus, at the Veselo-Podol station in the Ukraine and the Ramon station in the district of Voronezh, since the beets of these stations are outstandingly high in content of "harmful nitrogen" and ash. Up to the present time special attention has been given to working out a method of selection but no tangible practical results have been achieved in this direction (12).

Aims of Selection

Before the revolution the basic aim of selection at many of the breeding stations was toward increasing the sugar content. For this reason many varieties were outstandingly high in sugar. The same varieties served as original material in the beginning of selective work at Soviet breeding stations. To these belonged materials from the Nemercha agricultural station (formerly belonging to Buszczynski and Lazynski), the Verkhniachka station, Kalnik and Oudychsky breeding stations and also the Polish breeding station of A. Janacz. Thus the first lots of sugar beet seed released by certain Soviet breeding stations were definitely of the sugar type.

Soon, however, the type of sugar beet seed released was abruptly changed in the direction of the high tonnage type. The reason for this change was the shortage of raw material at the sugar factories. Varieties from stations Uladovka, Ivanovka, Ramon, Belaya Tzerkov and Lgov may be characterized as high tonnage beets. Sugar beet material of the high sugar type from Nemercha station and the stations Kalnik and Oudychsky were preserved and turned over for further breeding work to stations Vesely Podol and Yaltushkovsk, where the varieties continued to be of the high sugar type.

At the station Verkhniachka, a normal type of beet was produced by crossing the high sugar types of this station with high tonnage beets.

From 1934 on, the normal type of sugar beet which combined sufficiently high sugar content with sufficiently high tonnage took on great importance in the USSR. First among varieties of this type is the varietal material from Station Verkhniachka. Soon afterward a number of other breeding stations began to release lots of seed of the normal beet type, together with high tonnage types. Among these were the stations Uladovka, Lgov and Ramon.

The following breeding stations are active at present in the USSR: In the Ukraine Station Uladovka—selective breeder Dr. L. Sempolovsky (since 1898); Station Verkhniachka-breeder T. Grinko; Station Nemercha and Substation Yaltushkovsk—formerly directed by breeder L. Fedorovich, now by A. Popov; Station Belaya Tzerkov—breeder V. Yegorov; Ivanovka Breeding Station—formerly under B. Lebedinsky (died in exile), now under O. Helmer; Station Veselo-Podoliansk formerly under breeder I. Voitkevich (perished in the cellars operated by NKVD), now under V. Sukachev. In RSFSR—Station Ramon, under breeder A. Mazlumov (since 1922); Station Lgov—under breeder C. Goodwill.

New regions of sugar beet culture are located in these areas: Pervomaiskaya (May First) station in northern Caucausus; Bijsk station in western Siberia; Kirghiz station in middle Asia.

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CHEMISTRY AND FACTORY OPERATION

Design Factors Which Affect the Heat Balance of a Beet Sugar Factory

E. B. COLE[1]

For the past several years this writer has watched with considerable interest two specific items of operating data; namely, percent steam on granulated sugar, and percent fuel on granulated sugar. As we have increased our production and have modernized our plants these data have shown a steady and very gratifying improvement. I have often speculated as to just how far we can go in improving our factory heat balances, and have been on the alert for improvements in design which will enable us to achieve the practical maximum efficiency in the factory heat balance.

Curiosity has compelled me to make comparisons between the performance of our plants and those of our neighbors. Each year's final performance figures show a definite pattern in the arrangement of factories according to their thermal performance. There is a limited amount of shifting up and own scale, but the same factories usually fall within the same groups from year to year.

I have chosen a fuel unit of 1 million btu's which is equal to 100 pounds of standard 10,000 btu's per pound coal or 1,000 cubic feet of standard 1,000 btu's per cubic foot gas, and will compare this with a standard 100-pound equivalent bag of sugar on a percentage basis.

Of the 52 factories whose records were studied, I find that "Fuel percent on granulated sugar" ranged from 59.5 percent to 144.3 percent with the mean value at 88.2 percent. The first ten factories produced granulated sugar for 70 percent fuel on sugar or less. The last ten factories produced granulated sugar for 100 percent fuel on sugar or more. It is interesting to speculate on the amount of money which could be saved by the sugar industry as a whole if all the stragglers could be moved ahead into the less than 70 percent fuel on sugar group.

I have found that the data "Steam percent on sugar produced" are accurate measures of the thermal and process efficiency of the sugar factory and these data permit of an accurate comparison between Steffen and non-Steffen sugar factories.

It is this writer's opinion that there is still room for much improvement in reducing the amount of steam and fuel required to make granulated sugar.

To provide a basis for the remainder of this discussion a heat balance which might be typical of a most efficient beet sugar factory is presented in Table 1. This table does not attempt to present a detailed heat balance, but merely a form of summary sheet. This heat balance is in very close agreement with actual operating conditions at our Rupert and Nampa sugar factories, and represents a non-Steffen House factory.

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In addition to assuming Table 1 for steam requirements we will also assume that there is an amount of water to be removed by the evaporators equal to 105 percent on beets.

What is the minimum total steam requirement and how can that minimum be achieved? In this case, if the vapor circuits were so arranged that the 105 percent water on beets was completely evaporated in supplying vapors for the various heating requirements, then the irreducible minimum would be 58 percent steam on beets or 425 percent steam on sugar produced. At the other extreme, if live steam or exhaust were used for all heating requirements and the 105 percent water on beets was vaporated in a five-body multiple effect evaporator without vapor extraction, the total steam required would then be 79 percent steam on beets or 579 percent steam on sugar.

In neither of the above examples was there any waste of steam nor was there assumed any decrease in process efficiency. Thus, for this sugar factory there is a difference of about 21 percent steam on beets in the total steam consumption figure between full utilization of vapor for heating and no utilization of vapors for heating. This is a variation of more than a third in the total steam requirements.

The arrangement of the vapor circuit which will permit the most effective use of vapors for heating and which at the same time is extremely practical to operate and maintain is one of the most important design factors which affects the heat balance of the sugar factory. Table 1 also indicates a vapor circuit which utilizes vapors to a maximum and which at the same time is practical and thoroughly workable with present day equipment and methods. The flow sheet following the table indicates the approximate temperatures and pressures to be employed and also shows the location of the vapor recompressor in the circuit. The latter is the only novel feature of this particular vapor circuit. Time and space do not permit a detailed comparison of this vapor circuit with other circuits of modern design.

I should like to point out the effect that a change in diffuser draft has on the steam consumption of this typical factory and also estimate the effort that increasing the circulating load in the sugar end has on the heat balance. An increase in the draft of 10 percent on beets will raise the steam consumption to 67.90 percent on beets, an increase of 3.3 percent steam on beets. A decrease in draft of 10 percent on beets will lower the steam consumption to 61.84 percent on beets, a decrease of 2.76 percent steam on beets. An increase in the circulating load in the sugar end which would increase the stock in process by one-third would increase the steam consumption to 70.20 percent on beets, an increase of 5.60 percent steam on beets.

At this point I would like to discuss the much maligned thermal vapor compressor. It is nothing more or less than a steam injector with the suction line connected to the vapor line from one of the evaporator bodies; it discharges into the low pressure steam or exhaust line, and uses non-superheated live steam at boiler pressure as motive steam. The efficiency of this device is low, of the order of 25 percent at the very best, but compared to a mechanical vapor compressor its cost is very low and it is simple to operate.

Assuming that the power plant will supply 40 percent steam on beets in the form of exhaust to the evaporators and melters, then 14.60 percent steam on beets as makeup must come from some other source.

If third vapor is compressed from a five-effect exaporator, it will require 11.68 percent live steam on beets to recompress 4.87 percent third vapor to give a new total steam figure of 61.68 percent steam on beets.

For this particular plant, it is believed that a static thermal vapor compressor installation could pay for itself on a production of half a million bags of sugar. Don't be misled, unless the installation is favorable and is designed for optimum conditions, the returns might not justify the cost of the installation.

The quantities of steam and fuel required to make a bag of sugar are very nearly the same for either the Steffen House factory or a non-Steffen House factory. Any differences are due principally to the greater circulating load in the sugar end due to the higher burden of non-sugars in the sugar end of the Steffen House factory.

The power required to produce a bag of sugar is also very nearly the same for both Steffen House and non-Steffen House plants. This assumes that the plant is of a well balanced mechanical design with pumps and motors operating at near full load and that there is a minimum of pipe line friction, and line shafting with journal bearings and flat belt drives. This typical factory with an efficient process and steam circuit must have an efficient mechanical plant if it is to take full advantage of the economies of low pressure steam and power generation.

The boiler plant in a sugar factory is essentially a process steam producer and as such it should be designed to produce process steam at the lowest possible cost and make only as much power as an efficient mechanical plant will require.

What are the power requirements for a mechanically efficient sugar factory? A non-Steffen House factory should require not more than 20 kwh per ton of beets per hour or 7.33 kwh per bag of sugar per hour. A Steffen House which works a reasonable amount of molasses, say 4.0 percent on beets, will then add 3 kwh per ton of beets per hour or 0.05 kwh per bag of sugar per hour. A pulp drier will add 3 kwh per ton of beets per hour or 1.1 kwh per bag of sugar per hour. A C. S. F. plant will add 2.0 kwh per ton of beets per hour or 0.75 kwh per bag of sugar per hour, and will consume exhaust at a rate which will produce at least twice as much power as is required by the C. S. F. plant.

Let's assume for the sake of easy figuring that this typical efficient sugar factory is a 2,400-ton per day factory with a pulp drier. It will then require 2,300 kwh, so we shall install a 2,500-kw generator which will operate at a load factor of 92 percent.

With all pans on it will require 54.60 percent exhaust on beets to process. With the white and intermediate pans off there is 40.20 percent exhaust required for process; this latter is the most unfavorable condition for the power plant. Therefore, we shall select steam conditions which will produce the required 2,300 kwh for 40 percent steam on beets to the turbine. Forty percent steam on beets in this case is equal to 80,000 pounds of steam

per hour. Thus, it is necessary to generate 2,300 kwh with 80,000 pounds of steam per hour or one kwh for 34.8 pounds of steam per hour.

A look at the flow sheet reveals that the maximum back pressure is 35 psia or about 21½ pounds gage saturated at the elevation of our Nyssa factory. Resorting to a Mollier steam diagram and a table of steam rate factors, we find that throttle conditions at the turbine need be only 177 pounds gage and 492° F. total steam temperature, or a superheat of 115° F.

This same plant with the addition of a Steffen House and C. S. F. plant would require 2,800 kwh, and would have a 3,000-kw generator which would consume a minimum of exhaust steam to process of 109,000 pounds per hour. The steam rate for the turbine would be 38.9 pounds of steam per hour per kwh. Throttle conditions in this case would be 147 pounds gage at 468° F. total temperature of 102° F. superheat.

Let's compare this plant with another one which has an identical process and low pressure vapor circuit, but instead operates with an exhaust pressure of 50 psi absolute or 36½ pounds gage, saturated steam conditions. To generate 2,300 kwh with 80,000 pounds of steam per hour or at a steam rate of 34.8 pounds of steam per hour per kwh will require throttle conditions of 256 pounds gage at 520° F. total temperature or a superheat of 114° F. This same plant, but with Steffen House and C.S.F. plant, would require throttle condition of 217 pounds gage and 495° F. total temperature or 100° F. superheat.

Which of these two boiler and power plants is the more efficient?

The low pressure plant is very slightly the more efficient plant. Reference to a steam turbine handbook will bear out the point that the overall engine efficiency of a standard steam turbine generator set below the size of 7,500 kw is usually a few points better for the lower pressure machines. In this case, the 180 psig machine had an overall engine efficiency of 69 percent while the 260 psig machines had an overall engine efficiency of 68 percent. The actual steam rate in both cases was the same, as was the load factor.

A comparison of boiler efficiencies under conditions of identical design, and identical and optimum combustion practices, shows that the lower pressure boiler will have a flue gas temperature 30° F. lower than the higher pressure boiler and an overall efficiency of 0.9 percent point higher than the higher pressure boiler.

These two boiler and power plants are very nearly of the same efficiency with a slight advantage in favor of the lower pressure plant. Both sets of steam, exhaust, and power conditions represent good design.

Now let's compare both of these plants with one which operates at a steam pressure of 450 pounds gage pressure and a total steam temperature of 575° F. and produces exhaust at 36½ pounds gage pressure. Referring to the Mollier chart and the steam turbine hand book we find that the actual steam rate is 27.2 pounds per hour per kwh; the load is 2,300 kwh at a load factor of 92 percent; the overall engine efficiency is 66.6 percent and the quantity of exhaust steam produced is 62,600 pounds per hour of exhaust at 36½ pounds gage and 1.3 percent moisture, or 31.3 percent exhaust on beets.

How will the boiler efficiency of this last power plant compare with the first two? Under identical conditions of design and operation the last boiler plant will have a flue gas temperature which is 81° F. higher than the boiler plant which operates at 177 pounds gage and will suffer an additional loss of 2.1 percent in boiler efficiency compared with the 177-pound boiler plant.

Up to this point I have avoided mentioning the costs of building these three boiler, power plant, and evaporator stations. It should be obvious that the lower pressure plants are the least expensive to build. The low pressure plants can use standard weight pipe and 300-pound class fittings. The other plant requires extra heavy pipe and higher pressure fittings. In the standard class of turbine generators the first major price break is at 500° F. temperature and 250-pound design pressure. Furthermore, in order for the 450-pound boiler to compete with the 177-pound boiler in operating efficiency it will be necessary to add to the boiler an economizer, or an air heater, at an added cost.

Table 1.

Percent Sugar in Beets					16.10%	
Total of Known and Unknown Losses					0.45%	
Sugar in Molasses Produced					2.00%	
Sugar Produced					13.65%	
Extraction					84.8 %	
Steam Requirements	**Total**	**Stm.**	**Exh.**	**1V**	**2V**	**3V**
Diff. and R. J. Htr.	11.50			3.50	3.50	4.50
J. Blr. or 2nd Carb.	3.50				3.50	
Tn. J. Htr.	6.25			4.00	2.25	
Tk. J. Htr.	1.10				1.10	
White Pan	12.00			12.00		
Int. Pan	6.00			6.00		
Raw Pan	3.65				3.65	
Melters	1.50		1.50			
Granulators	1.50				1.50	
Misc. Heating	1.00				1.00	
Beet Slicers	1.50	1.50				
Rad. and Unknown	8.50	3.50	5.00			
	58.00	5.00	6.50	25.50	16.50	4.50
1 x 25.50 = 25.50					105	
2 x 16.50 = 33.00					— 72	
3 x 4.50 = 13.50					5)33	
46.50	72.00				6.60	
					46.50	
% Ehaust to Evaps.					53.10	
% Exhaust to Melters					1.50	
% Exhaust to Process					54.60	
% Steam to Slicers					1.50	
% Steam and Exhaust Losses					8.50	
% Steam on Beets					64.60	
% Steam on Sugar					473	
% Fuel on Sugar					55.7	

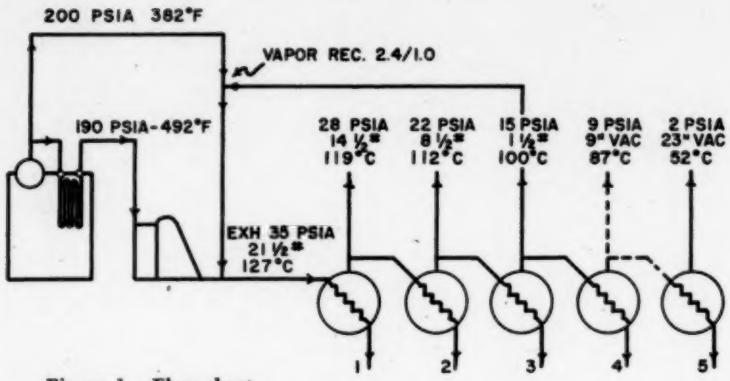

Figure 1.—Flow sheet.

Thus, in order to produce sufficient power and produce process steam for a beet sugar factory at the lowest possible first cost and operating cost, I would choose the boiler plant and turbine which operate at no more than 200 psia and 500° F. total temperature.

I would like to point out that, in order for a plant to be capable of the most efficient heat balance, it must have an efficient and capably managed process, it must be sparing in its use of steam at each heater or process station, the arrangement of the vapor circuit must take full advantage of the economies of multiple effect evaporation, and lastly—the boiler and power plant must be designed to produce steam and power at the lowest possible cost.

The steady trend toward more complete mechanization within the sugar factory is in step with the times. However, care should be taken to see that the mechanical devices which are installed are efficient in their use of power, and that their use of power is justified. Mismatched motors and pumps can waste power, oversize motors can waste power and lower the power factor, awkward piping arrangements and undersized pipe lines can waste power. In fact, it demands continuous vigilance to be sure that, as equipment is added or changed, the power system is not overloaded.

In conclusion, I would like to state that it is possible to build and operate efficiently a sugar factory which will produce sugar for 60 percent fuel on sugar or less, and this sugar factory need not operate its boiler at more than 200 pounds pressure. In fact, the low first cost low pressure plant will also produce steam, power and sugar at the lowest possible operating cost.

I hope that the presentation of this paper will promote a discussion which will continue long after this meeting has been adjourned.

Increased Sugar End Capacity at Betteravia Resulting from Changes in Equipment and Operation

ALLAN WOODS[1]

In 1950 Union Sugar decided to continue its program of expanding the factory capacity by taking steps to increase the efficiency and capacity of the sugar end production. Prior to this decision a new white pan and three new evaporator bodies had been installed to replace worn out equipment. A Silver continuous diffuser had been installed in 1947 which easily furnished enough slicing capacity to overcrowd the sugar end. After reaching this decision, the following steps were taken beginning in the early part of 1951:

1. The old, slow speed, belt-driven low raw centrifugals were replaced by seven new fluid drive 40 x 30 centrifugals built by the Western States Machine Company. At the same time, Blanchard-type cooling coils as used by the Utah-Idaho Sugar Company were installed in six of the old air-cooled crystallizers.

2. In 1952 the low side boiling system was supplemented with a new 1,300 cu. ft. calandria pan and four more Blanchard-type cooling coils were installed to bring the total number of water-cooled crystallizers to ten. The size of these crystallizers is such that each crystallizer will hold one-half the contents of a low raw pan (approximately 600 cu. ft.).

After these two steps the practice of putting all the low raw sugar through the intermediate pan was discontinued (see Table 1). The low raw sugar, after being washed to 97.5-99.0 purity[2] by a 60-second application of water at the end of the cycle, was introduced directly into the standard liquor, thence to the white pan.

This procedure, combined with the control of the wash water and green syrup purities gained by manipulating the syrup separators on the intermediate and white centrifugals, was used to produce uniformly controlled purity syrups going to the three stages of boiling. All our mixers are equipped with mingler coils to facilitate the handling of the massecuite and the action of the separators.

Thus, with a normal thick juice purity of 90 coming from the evaporators, the purity of the white massecuite is maintained uniformly from 93,[6] to 94 purity. The quality of the white sugar produced under these circumstances is of a high standard.

An additional advantage was encountered in this procedure, in that the reintroduction of large amounts of non-sugars into the process was avoided, the amount of white massecuite to boil for a given production of

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[1] Factory Superintendent, Union Sugar Division, Consolidated Grocers Corporation, Betteravia, California.

[2] The purities referred to in this paper are apparent purities only in the absence of raffinose, which is not encountered at Betteravia.

white sugar was materially reduced, and the total amount of all massecuites boiled per unit output of white sugar was reduced. This has meant a considerable saving in steam to the pan floor, greater production per man hour, and less loss of sugar through process losses and chemical changes. In terms of beet slicing capacity, which is critical in California factories where no piling is done, this change has resulted in a slicing increase of 200 to 400 tons capacity on the beet end.

The sending of melted raw sugar through the intermediate pans prior to introduction into the head of the process has been eliminated except under extraordinary circumstances.

Washing of the low raw sugar to high purities depends upon the maintenance of good grain characteristics in the low massecuites. As a result, the boiling procedures have been carefully scrutinized to insure the production of even-grained, smear-free massecuites with good purging qualities. A minimum boiling time of eight hours or longer if possible is adhered to. The absence of unmelted grain in the syrups and the uniformity of the purities greatly facilitates this procedure.

As outlined in Table 1, the purity of the intermediate pan is carried at approximately 87 purity, which gives maximum crystallization under slow boiling procedures taking from 3 to 3½ hours. The purity of the low raw pan is regulated between 75.5 and 76.5, shooting for an average of 76 purity.

Table 1.

PRIOR PRACTICE (1950)	NEW PRACTICE (1953)
White Pan Boiling	
I. White Massecuite 92.5 to 93 Purity Components: a. Evaporator thick juice 90 Purity + High Raw Sugar 97 to 99 Purity b. Wash water from White Centrifugals at 92-93 Purity	I. White Massecuite 94 Purity Components: a. Exaporator thick juice 90 Purity b. High Raw Sugar 99 Purity c. Washed Low Raw Sugar 98 Purity d. Wash Water from White Centrifugals 94 Purity
High Raw Pan Boiling	
I. High Raw Massecuite 87.1 Purity Components: a. High Green from White Centrifugals 86.5 Purity b. Wash water from High Raw Centrifugals 84 Purity c. Unwashed Low Raw Sugar 92.8 Purity	I. High Raw Massecuite 86.8 Purity Components: a. High Green from White Centrifugals 87.5 Purity b. Wash Water from High Raw Centrifugals 84 Purity
Low Raw Pan Boiling	
I. Low Raw Pan Crystallizer Mass. 75.7 Purity Components: a. Low Green from High Raw Centrifugals + Low Wash, if necessary Molasses Purity—56.1	I. Low Raw Pan Crystallizer Mass. 76.2 Purity Components: a. Low Green from High Raw Centrifugals 75.1 Purity b. Wash Water from Low Raw Centrifugals 70 Purity c. High Green from White Centrifugals, if necessary Molasses Purity—56.4

This pan purity range has proven in our experience to give the best results, judging from the standpoint of purging qualities of the massecuite and purity of the final molasses. In the event the low green syrup purity drops below 75.5, owing to increased crystallization in the intermediate pan, the low raw pan charges are spiked with high green syrup to increase the pan purity and give a good grain foundation. This procedure is not difficult to control, due to the uniformity of the purities, and the information is easily recorded and transferred between the shifts.

Centrifugal Operation

Superheated water at 110° C. is used on the white machines together with the double washing system. This combination not only produces a better grade of sugar with less water and sugar loss, but also permits a sharp separation to be made between the wash and green syrups.

The intermediate and low raw massecuites are washed with water at 90° C. Double washing is used on the intermediate centrifugals and a single spray is applied on the low raw centrifugals approximately a minute and a half before the end of the cycle. The wash waters are returned to the pans as indicated in Table 1.

The time of application of the second wash water on the white and high raw machines is regulated according to the purities of the green syrups. In the case of low purities the separators are tripped five to ten seconds after the water is applied, which introduces the higher purity wash water into the green syrup. With high purity syrups resulting from fresh beets, the separators are tripped as the second wash is applied.

In the washing of the low raw centrifugals the separators are tripped when the wash water is applied, at which time approximately 95 percent of the impurities in the centrifugal charge has been eliminated. Thus the possibility of introducing sugar into the molasses by the wash water is avoided. The average purity of the low raw wash water at Betteravia is 70.

The low raw cycles are kept as long as possible, starting at approximately 25 minutes at the beginning of the run, and leveling off at approximately 15 minutes during peak operations. During the Imperial Valley season, with an extremely heavy burden on the low side resulting from spoiled beets, 98 purity sugar has been obtained with the cycles as short as 11½ minutes.

Table 2.—Comparative Operating Figures for Past Five Years (Coastal).

	1949	1950	1951	1952	1953
Average Daily Slice	2,206	2,243	2,790	2,635	3,097
Percent Sugar in Beets	17.02	16.03	15.90	15.51	16.01
Average Diff. Juice Purity	85.5	86.3	85.5	85.7	86.5
Average Sugar Production	6,191	5,906	7,303	6,826	8,451
Percent Molasses on Beets	5.16	4.69	4.68	3.98	3.75
Sugar in Molasses Percent on Beets	2.42	2.19	2.22	2.03	1.90
Apparent Purity of Molasses	56.3	56.2	57.0	56.5	56.2
Net Extraction (Percent of sugar entering factory)	82.72	82.22	82.50	83.04	85.20

The acceleration of the low raw centrifugals from loading until top speed has remained between four and five minutes. It has not been necessary to vary this acceleration time to produce good sugar.

Steam is carried on all of the centrifugals to keep the separators free and each centrifugal is steamed out thoroughly once a shift.

A partial summary of the operating results is given for the past five years in Table 2 for comparison of factory performance.

In summarizing the figures shown in Table 2, there is a decided increase in sugar end efficiency as evidenced by the reduction of the sugar going to the molasses, and in the decided increase in the volume of the average sugar bagged per day. The factory extraction has steadily improved and an increase in slicing rate has accompanied the change of equipment paralleled by the ability of the general personnel to make use of these changes. In 1952 the slicing rate was slowed down owing to harvest difficulties, but the overall efficiency of the sugar end did not drop.

The net effect of these changes is to speed up the entire factory operation, both in respect to handling an increased quantity of beets sliced and to efficiency increase the sugar end output.

Experience with Vincent Pulp Drier and Pneumatic Conveying of Dried Beet Pulp at Woodland

TEMPLE C. ROWE[1]

The Woodland Factory of Spreckels Sugar Company initiated pulp drying operations during the 1952 fall campaign. Facilities installed for that initial campaign provided drying of pulp from approximately 1,800 tons of beets per day. Woodland factory daily slice exceeds 3,000 tons, therefore, the balance of the wet pulp is pumped to the existing wet pulp silo.

All wet pulp from the Oliver Morton continuous diffuser is conveyed by screw conveyors above three pairs of Zenith Model ZL pulp presses. Each press is supplied from a chute controlled by a rack and pinion slide gate. Only sufficient presses are operated, each at full capacity, to provide the drier feed. The remainder of the wet pulp continues along the screw conveyor to a chute feeding the wet pulp pumps. Some presses rotate at 3 rpm, and others at 4 rpm, which enables drier feed to be altered by selection of various speed presses.

The pressed pulp is belt conveyed to two 20-inch diameter stainless steel ribbon mixing screw conveyors in tandem about 45 feet total length where molasses is added under pressure through 3/8 inch Marley spray nozzles. This molasses mixed pulp was initially fed into the driers through a rotating star type air lock feeder. However, this material built up in the sections of rotating air lock feeder, which hindered the drier feed rate. These airlock feeders have since been replaced by short tubular screw conveyor feeder sections, which give satisfactory results.

The two drier drums selected for Woodland were three-pass "Vincent 60B-180EH33 Vacuo Dehydrators" manufactured by the Dan B. Vincent Company of Tampa, Florida. Each unit was guaranteed to evaporate 22,500 pounds of water per hour from pressed pulp containing 83 percent moisture at a thermal efficiency of 1,500 Btu per pound of water evaporated. Actual operating data obtained over a 33-day campaign showed the drier efficiencies as listed in Table 1.

This style of drier has been used extensively on a commercial basis with citrus fruit wastes, alfalfa and fish meal.

The drier drum is horizontal and is somewhat unique in that the outside drum is stationary and only the two inner shells rotate. This feature enables the removal of pulp from the end of the second pass for recycling if necessary. The furnace is a cylindrical shaped steel-jacketed fire box with an annular air space around the periphery of the furnace shell. Air for the furnace is thus preheated as it is drawn through the annular space, which in turn provides a cooling of the furnace shell. Primary air necessary for proper combustion enters through a forced draft fan and secondary air enters through a refractory lining ring. Woodland furnaces are fired by either natural gas or fuel oil.

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[1] Engineer, Spreckels Sugar Company.

Table 1.—Woodland Pulp Drier 1953 Spring Campaign.

1	Dried Pulp Produced—3708.6 Tons at 10.8% moisture
2	Molasses Added—947.1 Tons at 79.97 RDS
3	Pressed Pulp—81.94% Moisture
4	Molasses addition—25.54% on Dried Pulp
5	Gas Consumed—34,503.2 M. Cu. Ft. at 1026 Btu per Cu. Ft.
6	Time Duration—1492 Drum Hours
7	Oil Consumed—9.13 Bbl at 6,300 M. Btu per Bbl.
8	M. Btu per Bag Dried Pulp Produced—464.5 M. Btu.
a	Loss assumed to be 10% on Dried Pulp Produced
	1. Water evaporated—17,167.34 lbs. per Hr. per Drum
	2. Thermal efficiency—1384.33 Btu per lb. H_2O Evap.
b	No loss assumed
	1. Water evaporated—15,211.10 lbs. per Hr. per Drum
	2. Thermal Efficiency—1562.36 Btu per lb. H_2O Evap.

Note: The fifth week of 1953 fall campaign showed the following efficiencies using 42.14% molasses addition:

a	Loss assumed to be 10% on dried pulp produced
	1. Water evaporated—16,128 lbs. per Hr. per Drum
	2. Thermal Efficiency—1268.87 Btu per lb. H_2O Evap.
b	No Loss assumed
	1. Water Evaporated—13,929.05 lbs. per Hr. per Drum
	2. Thermal efficiency—1469.22 Btu per lb. H_2O Evap.

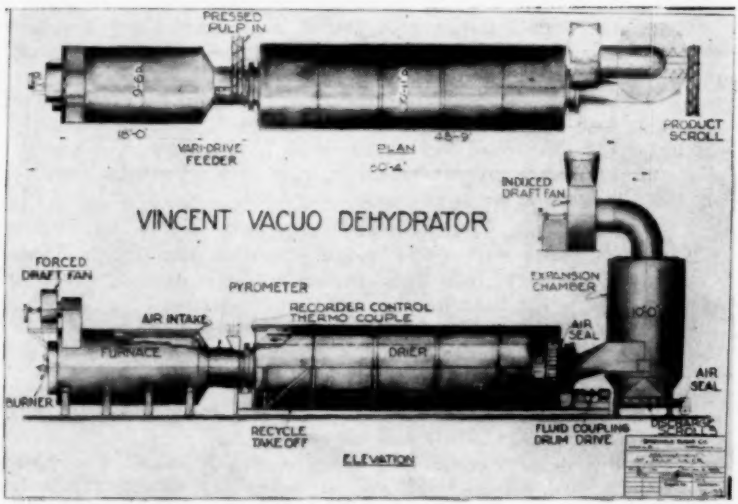


Figure 1.—General Arrangement of Drier.

Drier controls consist of a potentiometer-type pneumatic recorder controller which senses the temperature in the third pass and resets the index on furnace throat pyrometer temperature recorder controller to adjust for any load change. The pyrometer controller in turn pneumatically adjusts the forced draft damper and fuel supply control valves.

Each drum is equipped with a "fail safe" electrical control system which is approved by the Factory Insurance Association. If a fire develops in

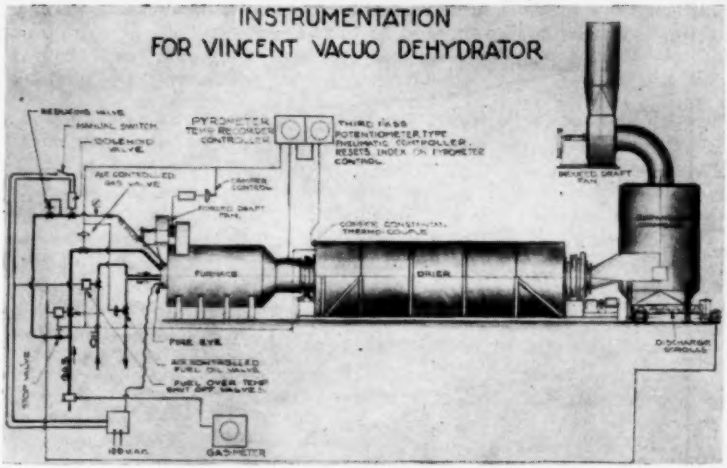


Figure 2.—Instrumentation Diagram.

either drum, a thermocouple in the third pass detects the resulting increased temperature. When third pass temperature exceeds maximum set point of 450° F., the over temperature circuit shuts off the induced and forced draft fans, fuel safety shut off valve, and the product collecting screw conveyor. A selector switch in forced draft fan circulit can then be set to remove troubled drum from "fail safe" circuit, and the product collecting screw conveyor started manually to continue with one-drum operation.

To resume drier operations after difficulty has been corrected, the product collecting screw conveyor is set to the "fail safe" circuit for both driers and restarted, followed by the induced draft fan, and the forced draft fan. By starting the forced draft fan, a time delay relay is energized preventing the main fuel valve from being opened, thus providing adequate time for furnace and drum purge. Should the poilot light be extinguished, the complete purge sequence would be repeated. When the first time delay relay was energized, this would energize a second time delay relay on the pilot circuit. At expiration of purge period, the induced and forced draft fans would be shut down. This second time delay relay on pilot system would allow time for operator to manually energize pilot valve to open and light pilot light by hand. As soon as the pilot light is lit the "Fire-eye" takes over and permits energizing circuit to main fuel valve. Normal sequence of bringing the drier on the line can then be followed. An annunciator alarm panel is incorporated as an aid to the operator so that he can instantly locate point of any drier system irregularity or failure.

Woodland Factory Pneumatic Dried Pulp Conveying

Located at discharge of drier product screw conveyors is a product collecting screw conveyor, elevator, and a Merchen continuous scale which discharges into a rotary air lock feeder. This feeder drops the product

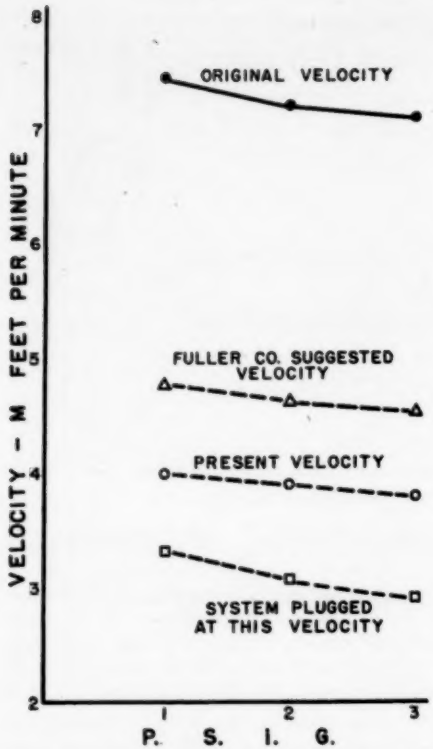


Figure 3. — Air Velocities Tried in the Woodland Pneumatic Conveying System.

into a Fuller Company airveyor system. The airveyor system is made up of a No. 1626 Sutorbilt Blower (driven by a 150 h.p., 900 rpm, T.E.F.C. motor), a 14 inch blower discharge pipe to a venturi-type product inlet beneath air lock feeder, and 10 inch delivery pipe to warehouse. The product travels approximately 710 feet to the warehouse, where it has free discharge 100 feet to floor of warehouse. All bends in the 10 inch conveyor pipe are made on an 8 foot radius except final 90° cornucopia type outlet in center of warehouse.

The Fuller Company supplied this pneumatic system as a package unit. Original design deliberately provided for future conveying of 3.3 times the present capacity, accounting for the apparent excessive size of equipment. At original design capacity, this system was set up to operate at a pressure of 7 PSIG (considered a high pressure system) as indicated between blower and feeder. Actual operations showed this pressure to be between 2 and 3 PSIG (classified as a low pressure system).

Figure 3 shows the various air velocities tried in the Woodland pneumatic conveying system. (Material travels at approximately 80 percent of air velocity in pneumatic conveyor, as per "Conveyors and Related Equipment" by H. G. Hudson).

The original air velocity of 7,250 FPM at 2 PSIG in this pneumatic conveyor most certainly delivered dried pulp to the warehouse. However, soon the local pulp trade expressed some dissatisfaction with the lack of bulkiness of the Woodland pulp; that is, there were too many fines.

Our interest in possible improvements of the product, as delivered to the warehouse, led to review of airveyor conditions. First hand investigation of other pneumatic conveyors conveying dried pulp revealed they were operating with an air velocity considerably below the Woodland airveyor system velocity. Further discussion with the Fuller Company produced their recommendation of 4,500 FPM at 3 PSIG. Subsequent tests showed an improvement in product bulkiness at this reduced speed. Still further velocity reductions were attempted. Finally, with air velocity of 3,250 FPM at 1 PSIG, the 10 inch delivery pipe plugged at the base of a relatively steep incline.

Having established a known "break point," the blower speed was revised upward to supply air at 3,975 FPM at 1 PSIG. This air velocity was used during most of the 1953 fall campaign.

The following are comparative typical screen analysis of random samples of pulp obtained:

1. After air conveying at original velocity, warehousing, recovery, and packing during 33 day, 1953 spring campaign.

2. After air conveying at revised velocity, warehousing, recovery, and packing from one month during 1953 fall campaign.

Table 2.—Dried Pulp Screen Analysis.

	7,250 F.P.M. Velocity—1953 Spring		3,975 F.P.M. Velocity—1953 Fall	
Screen Size	Product at Drier—%	Product in Sacks—%	Product at Drier—%	Product in Sacks—%
+ 5	0.41	0.06		
+ 6	7.40	1.94	9.2	2.90
+10	58.87	32.41	55.76	44.29
+20	29.37	46.36	30.26	43.05
+28	2.54	7.40	2.94	5.04
+35	0.83	3.65	1.06	2.12
—35	0.58	8.50	0.76	1.73
—20 Total	3.95	19.28	4.76	8.89

The western dairy trade desires a pulp that contains a total —20 fraction of no more than 11 percent, and prefers this fraction below 8 percent. Tests have shown that our present recovery system may account for approximately 43 percent of the breakage between drier and sacked product. One particularly desirable feature of the pneumatic conveyor results from cooling and vapor removal of the pulp enroute to the warehouse. The airveyor, as operated in present condition, appears as a reasonably satisfactory dried pulp conveyor.

Lime Kiln Design and Operation

A. A. CLARK[1]

Lime Kiln Design

Historically the lime kilns used in the domestic beet sugar industry have been, and still largely are, of the mixed feed, truncated, vertical shell type. The vertical shells, lined with fire brick, have for the most part followed two design patterns. One, the so-called "Belgian" type ("A," Figure 1), is set up on columns with an open bottom some four or five feet above the operating floor, this lower opening having cross bars so arranged as to support the lime, permit the entrance of air for combustion of the fuel and also allow for drawing the burned lime as desired. In the other design, commonly called the "Kilby" type ("B," Figure 1), the flared shell rests directly on the floor and the lime is drawn from doors placed in convenient working locations in the vertical sides around the base.

The kilns presently in use vary more or less in dimensions and cubical capacity, but follow a general pattern as to size. It is generally recognized that, if mixed feed kilns are too big, they become unwieldy and harder to control. For the most part the upper limit of capacity is accepted as about 4,000 cu. ft. for the burning of about 100 tons of rock per 24 hours. The lower limit is determined by the 24-hour tonnages required. Practical operating cycles vary from 36 to 48 hours.

Initially the charging apparatus and operating practice in both types of kiln were essentially the same. The coke and rock were placed together, in predetermined proportions, in a skip-hoist bucket and discharged into the kiln down a chute and through a large, straight, stationary cast iron funnel. The maximum size of the rock used was rarely reduced below 8 to 10 inches in cross section, and most of the stone less than 4 inches in size was discarded as waste. Coke consumption ran as high as 11 to 12 percent on rock and was rarely below 9 percent.

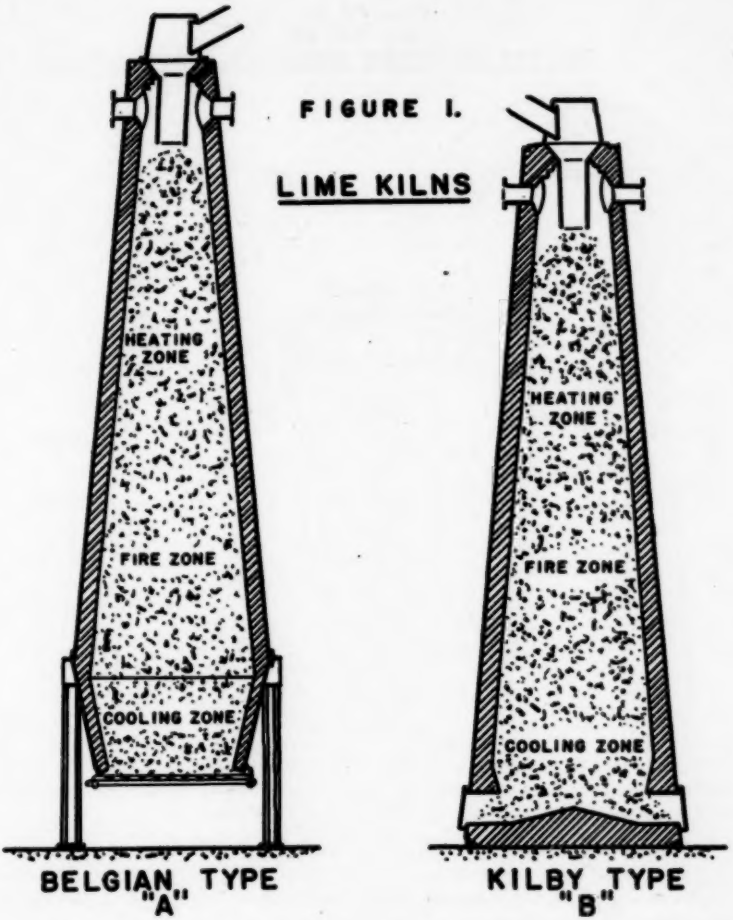
The results from operations under these conditions were far from satisfactory. A large percentage of the lime was either over or under burned and the fire conditions in the kilns were exceedingly erratic, often excessively hot both top and bottom at the same time and frequently causing severe damage to the kiln linings during the course of a campaign.

In due time, based on experience and observation, it became quite apparent that much of the difficulty in securing satisfactory kiln operation was caused by a distinct classification of the materials as charged, this classification being due, primarily, to the method of charging through a stationary central spout, coupled with wide variations in size of the pieces of charged material, which consisted of large and small pieces of coke, and large and small pieces of rock, with the pieces of rock predominantly larger than the pieces of coke. The classifying action due to variation in size of particles can be readily observed when such material as sand, gravel, coal, or even sugar, is built up into a conical pile. It will be immediately noted that there is a definite tendency for the larger pieces to roll to the outside of

[1] Assistant to the President, the Great Western Sugar Company, Denver, Colorado.

FIGURE I.

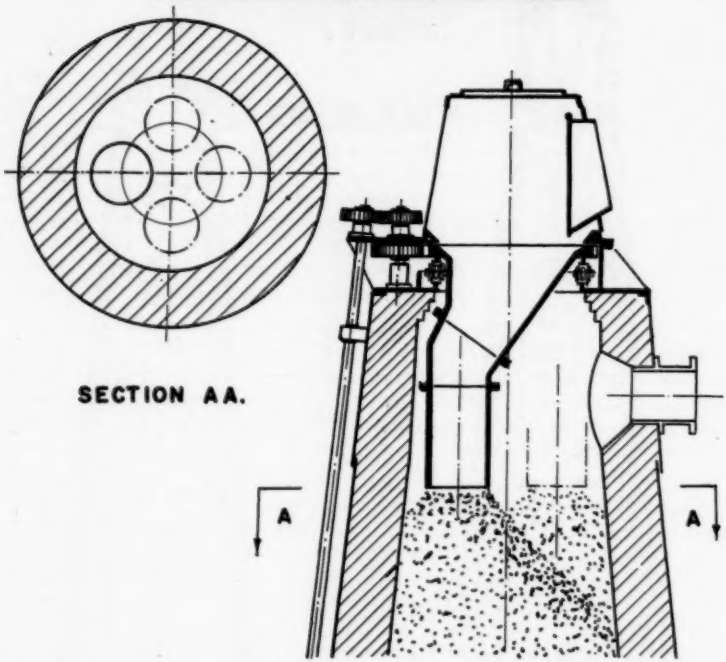
LIME KILNS



the pile, while the finer pieces are localized toward the center. The greater the difference betwen the smallest and the largest pieces in the mixture, the greater this tendency toward segregation.

That this segregating action often takes place in kiln operations is evidenced by erratic kiln burning conditions. The coke, as noted, being uniformly in smaller pieces than the rock, together with the fines and dirt, if any, in the rock, tends to localize at the center or possibly towards one side of the kiln, with the result that in such localized areas there is an over abundance of fuel and, due to the choking action of the fines, a lack of sufficient air for combustion. By the same token, in other areas there is a reduced amount of fuel with an excessive amount of draft, the net result

FIGURE 2.
LIME KILNS
ROTARY EXCENTRIC CHARGING SPOUT

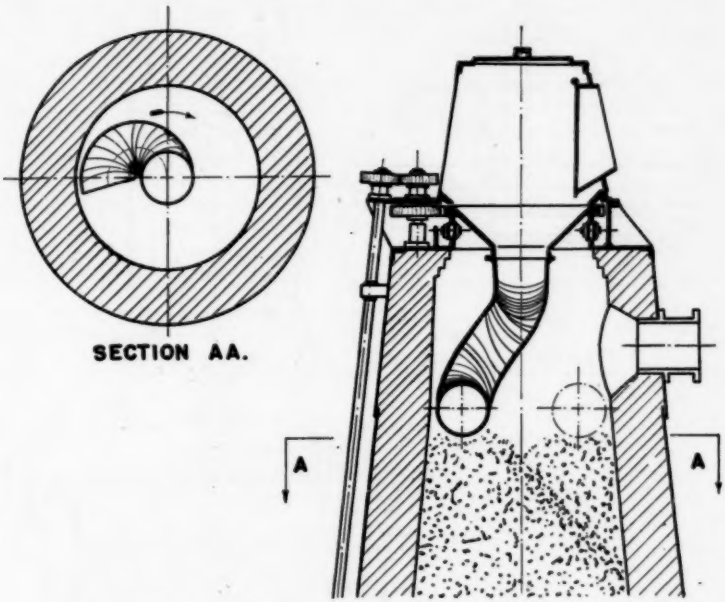


of this condition being that the fire climbs to the top in one section and remains persistently low in another section, the rock being under burned and over burned accordingly in these respective locations.

Having recognized that faulty distribution causes at least a large part of the difficulties in operation of mixed feed lime kilns, various changes in the design of charging spouts and apparatus have been made in an effort to improve this condition.

Given a predetermined percentage of coke and rock in the kiln feed, it appears logical to assume that if every piece of limestone was of the same size and composition as every other piece, and that if the coke pieces were all of uniform size and composition and were distributed uniformly so that there would be the same amount of fuel in each unit of cross section as in every other unit of cross section of the kiln, then both the heat required and the heat available would be completely uniform throughout the burning zone and the lime produced would be of a correspondingly uniform quality. Naturally, in practice such ideal conditions are impossible. Nevertheless this being the ideal goal, any progress, however modest, in this direction should show at least some beneficial results.

FIGURE 3.
LIME KILNS
ROTARY SPIRAL CHARGING SPOUT

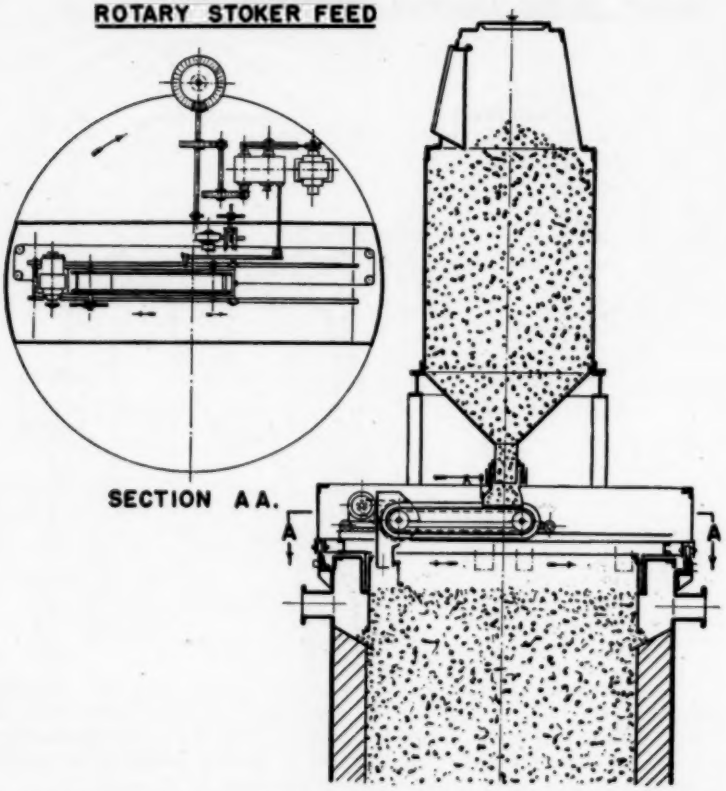


One of the first things tried was to reduce the rock to a more uniform size, this being done by reducing the maximum to about 5 inches in cross section. The larger pieces of coke were also broken up to prevent localized overheating due to concentration of fuel in the big lumps. This helped some, but still the results left much to be desired.

The next attempt at improvement was a series of modified charging spout designs, one being the offset rotary charging funnel (Figure 2). This funnel was designed to be turned more or less uniformly by a gear and hand wheel assembly, with each skip of rock. The improvement from this arrangement was quite definite. Instead of the rock and coke being piled up in a cone in the center of the kiln so that the larger rock rolled to the outside and the coke, which is usually much finer than the rock, being concentrated in the center, as per the action previously described, the material was spread somewhat more evenly around the circular cross section at the point of discharge. With the use of this offset rotary spout, coke requirements were reduced somewhat and lime quality improved. Many kilns at present are equipped with this type of charging apparatus.

Since even with the rotating offset spout the fire conditions in the kiln are far from uniform, the design in some cases has been modified in a

FIGURE 4.
LIME KILNS
ROTARY STOKER FEED

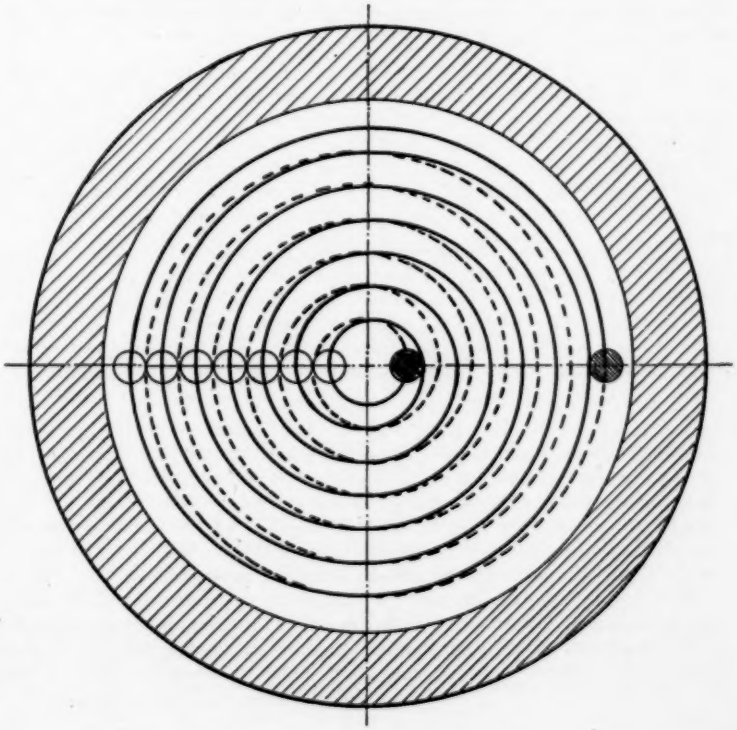


further attempt to improve distribution. This modified rotating design (Figure 3), which in shape has some of the characteristics of a spiral ramshorn, was aimed at further improvement in fuel distribution. It will be readily seen from observation of the action of the mixed feed as discharged from the skip to the chute into the top of the kiln that the coke, being lighter and finer than the rock, tends to lag behind and slide down the charging chute much slower than the heavier and larger pieces of limestone. The result of this lag, particularly with respect to the lower fraction of the fuel fines, with the straight offset funnel, is to concentrate an excessive amount of fuel on a circle traversed by that segment of the vertical portion of the charging spout nearest the center of the kiln, resulting again in an undue localized concentration of fuel. The spiral spout changes the angle so that the discharge takes place in a semi-horizontal manner somewhat tangentially to the circle of spout rotation. This carries the fines nearer the circumference of the kiln. The results of this modification are

somewhat better than with the straight offset charging spout; however, evidence of faulty distribution is still apparent.

A comparatively recent modification in the charging apparatus is quite a radical change from any of the previous arrangements. This latest design (Figure 4) is of a rotary stoker feed type. To accommodate this design the shape of the kiln shell was changed from a truncated cone to a straight vertical cylinder having the same diameter top and bottom. The top, covering the entire cross section, is set on trunions and rotates at a uniform rate. On this rotating top is mounted an oscillating carriage supporting a pan conveyor over which is located a stationary hopper for receiving the rock and coke mixture from the conventional skip. The stationary hopper, being located over the vertical center line of the kiln, feeds onto a slowly moving pan conveyor which runs at a uniform rate and, within reasonably narrow limits, carries a uniform load of the mixed feed. As the kiln top rotates the pan conveyor with its carriage and discharge spout oscillates back and forth along the radius of the kiln top circle (Figure 5), such oscillations

FIGURE 5.
LIME KILNS
PATH OF ROTARY STOKER FEED SPOUT



being graduated by a variable pitch screw arrangement so that the amount of material desposited in each unit of cross section area is the same and the rock and coke, as charged, remain level across the horizontal kiln section. This design largely obviates the segregating action which takes place with a fixed or semi-fixed discharge spout design. In the operation of one such kiln charging installation coke consumption, over a number of years, has been consistently about 10 percent less than with other types of design and quality of lime produced has compared favorably with that produced elsewhere. Difficulty with clinkers has been practically eliminated.

Lime Kiln Operation

Irrespective of design, experience has shown that there are some basic principles of kiln operation which should be observed for reasonably uniform results. Gas pumps and/or exhaust fans when once set to the desired kiln capacity should not be changed as to volume of gas drawn from the kiln. When for any reason such change is necessary, the change, especially to increased volume, should be made gradually. A radical increase in air taken to and through the incandescent fuel in the burning zone obviously will increase the rate of combustion, with a consequent increase in temperature, which may result in serious clinkering. Slowing the rate of gas exhaustion without the addition of more fuel, which additional fuel cannot become effective until about half the kiln cycle time has elapsed, will result in incomplete burning of the rock.

Care should be exercised to keep the rock and coke charged to the kiln as free as possible from dirt and excessive fine material. The dirt acts as a flux, reducing the fusing temperature in the burning zone and increasing the danger of clinkering. The fines in general tend to clog the draft in localized sections and by the same token increase the draft velocity in other sections with additional danger of forming clinkers. Vibrating screens of suitable mesh opening on both rock and coke before the skip are desirable.

A word here may not be amiss as to the method of starting the kilns just prior to the beginning of the beet slicing operations. Excessive fuel, whether wood or coke, in the initial charge should be strictly avoided. If it is desired to have lime of a normal and satisfactory quality when starting up, then normal lime burning conditions must be established and maintained. This means normal time and temperature as they exist after operations are under way.

Naturally at the very start, since the kiln burden and kiln brick work are cold, running conditions cannot be exactly duplicated, but they can be approached. If the normal kiln cycle is 36 to 48 hours, then this time cycle indicates the time allowance before slicing of beets, when the kilns should be started. The fuel in the first one-third of the initial charge may be increased, possibly by as much as 50 percent above normal. The balance of the charge should carry the normal operating percentage of coke. If this is done, then the kiln draft, after the fuel in the first one-third of the charge has been largely consumed, can be set at the normal campaign operating rate. Normal fuel and normal draft should result in normal kiln temperatures in the effective burning zone, with resulting normal quality of lime.

Factory Automatic Control Methods

SYLVESTER M. HEINER

The object of this paper is to show to what extent the Amalgamated Sugar Company has gone into automatic controls and to discuss the merits of various applications and methods used.

Fundamental Control Concepts

There are three principal control effects usually found in part or complete in all present day controllers whether they may be air, liquid or electrically operated. The three effects are "Proportional Response," "Automatic Reset," and "Derivative Response," or "Preact."

"Proportional Response" is the most common effect found in practically all controllers. Proportional response gives valve movement proportional to pen movement.

"Sensitivity" is a measure of proportional response and its units are psi per inch of pen travel. "Gain" is a measure of proportional response and its units are psi per psi. "Throttling Range" is a measure of proportional response and is defined as percent of full instrument scale through which the controlled variable must change to give full valve travel.

"Automatic Reset" may be defined as a response giving valve velocity proportional to pen displacement from the set point. The units of reset rate minutes (1)[1] or the number of times per minute that automatic reset duplicates the proportional response caused by the disparity between the pen and the set point.

In order to determine the reset rate on an instrument without a calibrated dial it is only necessary to move the pen away from the set point enough to cause a one psi change and observe the additional one psi changes per minute.

"Derivative or Preact Response" gives an additional valve movement proportional to the rate of pen movement. Since preact response is an additional output pressure change per rate of pen movement its unit is the preact time in minutes or—

(psi) per (psi per minute) = minutes

Figure 1 illustrates all three control effects:

1. The throttling range adjustment is represented by the diagonal lines.
2. The vertical translation of the family of curves shifts the control point.
3. The effect of reset is to horizontally shift the family of curves to the new control point requirement.
4. The effect of derivative response is to rotate the family of curves about the control point at a rate proportional to pen movement.

A purely mathematical approach to the problem of automatic control involves trignometrical and expotential functions which often call for an

[1] Numbers in parentheses refer to literature cited.

analog computer for the final solution, which puts the solution beyond the scope of the average engineer. There is a mathematical approach, however, which gives good results. The method involves the term ultimate sensitivity

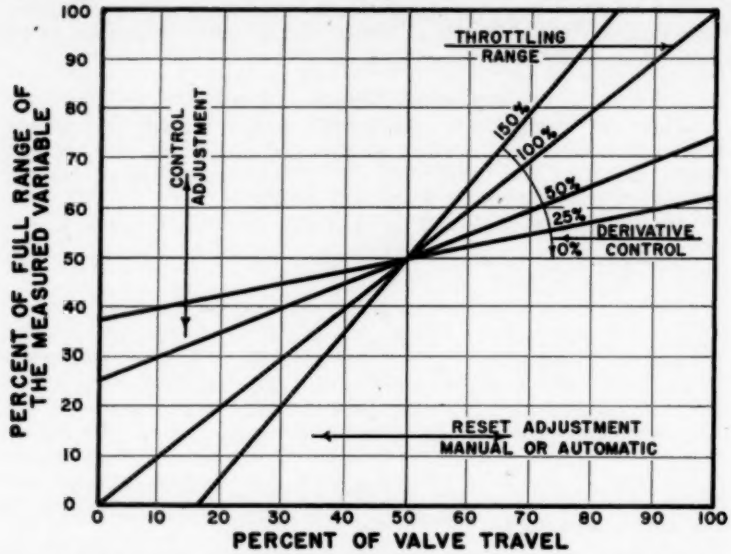


Figure 1.—Graphic Representation of Control Functions (Reference No. 1 by C. B. Moore)

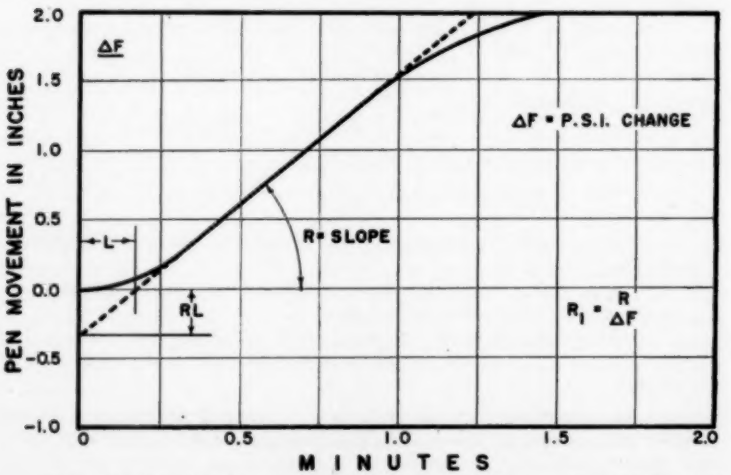


Figure 2.—Typical Process Reaction Curve (Reference Nos. 2-5 by J. G. Ziegler- N. B. Nichols)

(Su), which may be defined as that sensitivity above which any oscillation will increase and below which it will diminish to straight line control. The term period of oscillation (Pu) at ultimate sensitivity is also involved and is defined as the time for one complete cycle.

The solution also utilizes a process reaction curve. The reaction curve may be either calculated or observed. Suppose a process is on manual control under a steady stated condition. The control output is then increased ΔF psi. The curve shown in Figure 2 would result.

The approximation consists of drawing a line tangent to the point of inflection of the curve and saying that the process is represented by the simpler curve consisting of a dead period "Lag L" and a reaction rate "R." If the controller is set to give a valve movement ΔF for pen movement "RL" stability will result or sensitivity $= \frac{\Delta F}{RL}$

Unit Reaction Rate $R_1 = \frac{R}{\Delta F}$

Summary of controller adjustments;

For proportional response; Sensitivity $= .5\ Su = \frac{1}{R_1 L}$

For Proportional plus reset; Sensitivity $= .45\ Su = \frac{.9}{R_1 L}$

$$\text{Reset Rate} = \frac{1.2}{Pu} = \frac{0.3}{L}$$

For Proportional plus reset plus preact; Sensitivity $= .6\ Su = \frac{1.2}{R_1 L}$

$$\text{Reset Rate} = \frac{2.0}{Pu} = \frac{0.5}{L}$$

$$\text{Preact Time} = \frac{Pu}{8} = .5\ L^2$$

Preact response is usually used on applications which give a (Pu) period of oscillation greater than .4 minutes or a lag of 6 seconds or greater.

The advantages of reset response are obvious; however, it has two disadvantages in that it decreases stability and increases the period of oscillation.

Knowledge of control instruments is increasing. We are becoming more, should we say, "automatic control conscious?" However, the finest controller made when applied to miserably designed process may not produce the desired results. It, therefore, becomes more imperative that processes be more carefully designed from a control standpoint.

A formula for process controllability would contain—

1. Recovery factor = time lag, transfer lag and transportation lag.
2. Load factor = point in the process that the disturbance occurs, supply and demand side capacity, load change and frequency.
3. Mobility factor = the ability of the process to follow demands for different values of the variable.

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[2] See (2, 3) in literature cited for reference.

Time Lag: any reduction in time lag of a circuit is accompanied by reduction in the period of oscillation; also, the initial deviation following a load change is often reduced.

In designing a process a great deal of attention should be paid to minimizing time lag.

Transportation Lag: all transportation lags are undesirable and should be reduced to the minimum.

Transfer Lags: usually processes are made up of several transfer elements in series. A fair rule to follow is to eliminate or reduce all but the largest transfer element to a minimum value. The area under recovery curves is taken as a direct measurement of process difficulty and this area is shown to vary as the second power of the time lag. The importance of process design to reduce time lag is therefore quite obvious.

Zero load change means that perfect control would be possible with a fixed control valve setting; consequently, it is advantageous to minimize the frequency and number of load changes (4, 5).

With the above concepts in mind we have analyzed and tried to improve each station. A discussion of the Nyssa factory control system by stations follows:

Control of Beet Flow into the Factory

The rate of flow of beets into the factory is controlled by the beet feeder, which is manually remote controlled from the beet washer.

Automatic Flume Water Control

The beet lift pumps at our Nyssa and Nampa factories call for closer water control than is normally required in our factories without beet lift pumps. This is especially true during slow downs. This problem was solved by placing an 18 inch motor-driven butterfly valve in the flume supply line and controlling it from a B & W floatless control with the electrodes placed just above the suction of the beet lift pump. This control cuts off the water as it starts to rise in the flume and automatically turns it on as the water recedes.

Beet Slicer Control

The beet slicers are driven by three wound rotor motors with 50 percent speed adjustment giving a range of 62.5 rpm to 125 rpm. The drum switches are located at the diffuser control panel. The slicers are manually remote controlled to suit slicing requirements. The cossettes are weighed on an endless belt by a Merrick weightometer. The weightometer is equipped with a rateograph autosyn transmitter and a Foxborro motion transmitter. The motion transmitter transmits a pressure directly proportional to the projected hourly tonnage at that instant. The transmitted pressure is received on a recording Foxborro flow ratio controller. The tonnage slice is also recorded on a rateograph. The rateograph is used as a guide in adjusting the slicer speed to obtain the desired slice.

Automatic Water and Temperature Control of the Silver Chain Type Diffuse

The pneumatic impulse from the motion transmitter on the Merrick weightometer is used to position the set pointer on the flow ratio controller.

The ratio between air from the pressure transmitter and the positions assumed by the set pointer is adjustable, which provides a means of adjusting battery draft. The temperature of the diffuser supply water is controlled by a fixed high sensitivity controller. The diffuser water supply pressure is controlled by a pressure controller which bleeds back water from the discharge side of the diffuser supply pump to maintain a constant pressure on the orifice of the flow ratio controller at the diffuser. The controlled output of the flow ratio controller goes to a 6 inch valve in the diffuser water supply line. The valve is thus regulated according to the dictates of the flow ratio controller to maintain the desired draft.

The heating of the continuous diffuser is accomplished in the first five cells or less. Each cell has two heating compartments. The compartments are connected in multiple with a manifold on intake and discharge. The first cell can be connected directly to first vapor in an isolated manner. The diffuser is controlled by a temperature control and a pressure control. The temperature sensitive bulb can be moved from Cell 4 to Cell 3 and is usually located in Cell No. 4. Second vapor is admitted to the intake manifold through a 12 inch butterfly valve with a valve positioner. First vapor is admitted to the manifold through a six-inch throttle plug valve with a valve positioner. The valve positioner on the 12 inch valve is set to open from 2 to 7 psi of control air. The valve positioner on the 6 inch first vapor valve positioner is set to open from 7 to 15 psi of control air.

The diffuser temperature controller is a proportional response plus reset controller. The loading pressure from this controller changes the pneumatic set point on the pressure controller. The pneumatic-operated set point also has manual limit control. This is set at some limit valve, usually 5¾ pounds, which is less than the minimum value encountered on second vapor pressure. The pressure control is a proportional response plus reset controller. The control pressure from this unit is connected in multiple to the two valve positioners. The normal operation sequence selects second vapor and controls on second vapor unless the pressure drops or some unusual heating burden is imposed on the diffuser such as frozen beets. In this case the first vapor valve opens to meet the demand. The outlet manifold is vented to the domes of the first three cells, and to the incoming cossettes.

The diffuser controls have been very satisfactory.

First Carbonation, Second Carbonation and Sulphitation Control

All of our factories utilize the continuous Benning first carbonator or equivalent. Carbonation is controlled on a titration basis with a conductivity meter to show alkalinity trend.

Second carbonation is controlled by a pH controller on effective alkalinity basis. The pH of the controller is set to give the desired alkalinity. The type controller we use is a proportional response plus rest plus derivative response. However, we have succeeded in reducing the circuit lag to the point that derivative response is not required. The controller works in conjunction with a Beckman pH meter which measures the variable pH and transmits it to the controller. The controled output from the controller is applied to the CO_2 gas valve in the line to the gas manifold.

Sulphitation is controlled by a duplicate control system, except that the controlled air pressure is applied to a valve positioner mounted on diaphragm operator. The operator performs the following functions in the following sequence:

First, the primary damper on the sulphur stove is opened. Second, it actuates a mercury switch which in turn energizes the stove motor and starts the stove to rotate. Third, the trimming damper on the sulphur stove combustion chamber is closed. We use sulphur stoves at all our factories. In some cases we have mounted screw feed stokers to admit the sulphur to the stove.

The above method of controlling carbonation and sulphitation have been very satisfactory.

Automatic Lime Draw Control

Figure 3 shows the schematic arrangement involved in the automatic lime draw control system. Equipment involved consists of a Syntron VCR55

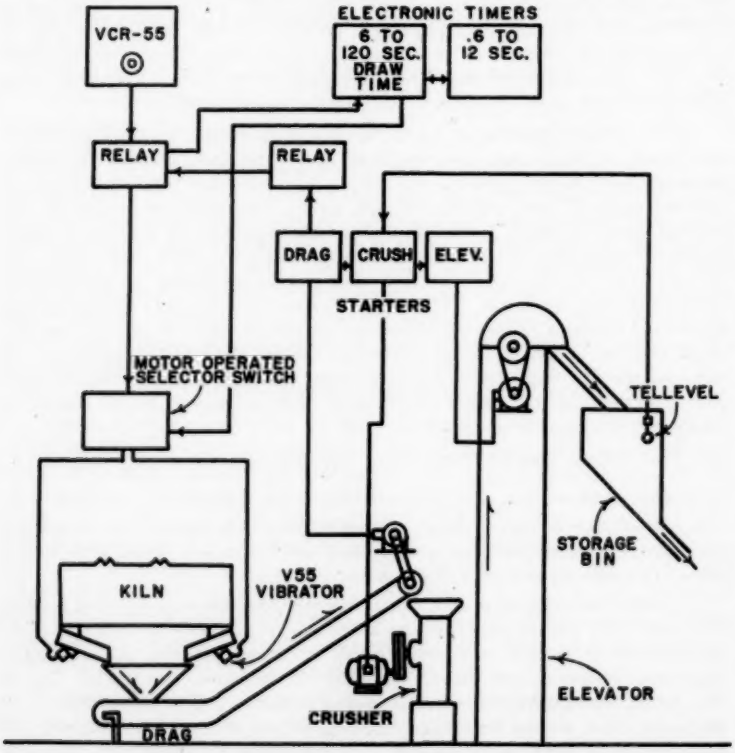

Figure 3.—Automatic Lime Draw Control System.

controller and four or six V55 vibrators. Control components consist of one 440-volt contactor, one 110-volt contactor, one motor-operated selector switch with positioning cam and limit switch, one draw-time electronic timer range, 6 to 120 seconds, and one seal-time electronic timer range, 6 to 12 seconds.

The above components function in the following manner to control the lime draw: The electrical components are electrically interlocked in this way. The draw system is in sequence with the drag conveyor, which is in sequence with the crusher, and the crusher is in sequence with the elevator. The tellevel exercises absolute control over the crusher. All drive units are on maintained contact control.

A sequence of events would be as follows: Suppose the crushed lime level drops in the storage bin below the tellevel. The tellevel starts the crusher, which starts the drag and then the draw system. By adjusting the VCR controller rheostat and the chute angles it is possible to keep the draw control operating continuously. The individual chute vibrating time is set on the draw timer. This determines the time an individual chute will draw until it advances to the next chute. The draw can be adjusted between chutes by adjusting the chute angle. Switches are provided for dropping any chute out of its normal operating sequence.

The principal advantages of the above system are:

1. Labor saving.
2. Lime is drawn continuously instead of batchwise.
3. Housekeeping under the lime kiln is greatly improved.
4. The kiln is charged continuously, which gives uniform gas temperature, and a more uniform percentage CO_2.

Automatic Lime Addition to the Coolers

Lime is fed to the coolers by Jeffry Taylor Waytrol feeders. A Jeffrey Taylor Waytrol consists of a belt mounted on a scale beam which automatically varies the lime feed to effect a balanced condition. The feeder is controlled by definite time relays. The time relays are controlled from a relay in the cooler motor circuit.

A sequence of events would be as follows:

The cooler is filled with mixed solution. The motor push button initiates the cooler cycle. The timing relays control preagitation time, liming time, and total time. The cooler is circulated for the agitation period and then lime is admitted during a definite liming period. The lime is automatically cut off at the end of the liming period and the cooler circulates on stand by until the operator is ready to discharge it and repeat the cycle.

Automatic Evaporator Control

The Taylor evaporator control system has been installed in all our factories. This system has proven itself to be a very valuable asset in a number of different ways:

1. It holds the levels in the respective effects at the optimum point for maximum evaporation and quick response.

2. It regulates the evaporation rate within limits to suit load fluctuations.
3. It discharges the thick juice at the desired Brix.
4. It provides a record of what has transpired.
5. It reduces the load changes on the boiler house.
6. It saves labor.

The control system as it now stands has 5 level controls, 1 juice tank level control, 1 first vapor pressure control, 1 exhaust steam make-up control, 1 fifth vapor pressure control and 1 Brix controller.

The evaporation rate is changed by the output of the juice tank level controller which positions a butterfly valve located in the vapor line between second and third effect.

The third vapor pressure controller has been replaced with an exhaust makeup controller.

The density controller has been changed to control the valve on the liquor into the fifth effect and the level control controls the valve out. The Brix control was definitely improved in all cases.

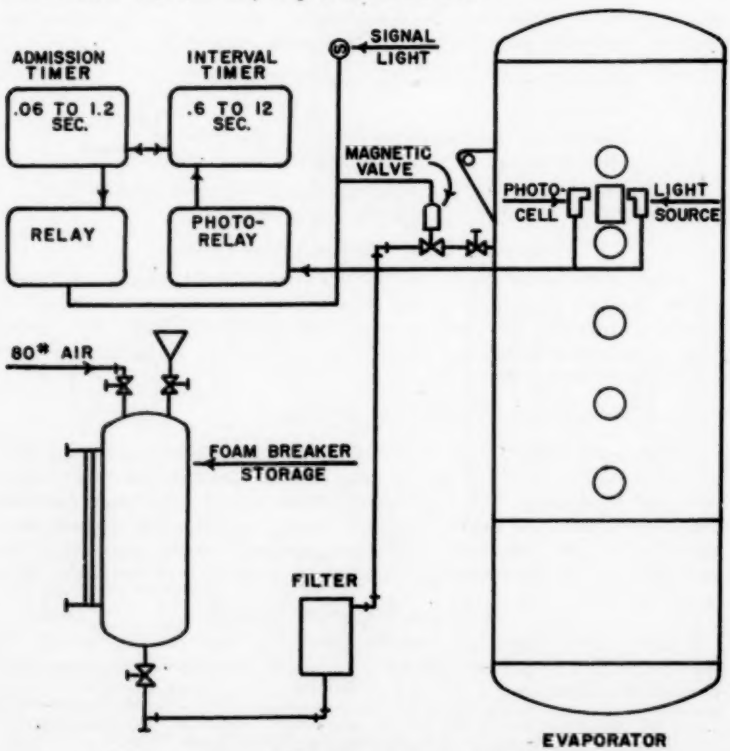

Figure 4.—Automatic Foam Control for Evaporators.

The evaporator control has been a very satisfactory piece of equipment.

The evaporator control system removed the evaporator operator and thereby left us with a potential foam carryover problem. The automatic foam control shown in Figure 4 consists of a photo electric cell, light source, photo relay, valve relay, magnetic valve and two electronic time relays and a filtered foam breaker source under pressure. A small side pocket is welded on the side of the effect which mounts two sight glasses on opposite sides. The photo cell and light sources are mounted on these glasses.

A sequence of events follows:

Assume that foam rises up in front of the photo cell. This actuates the photo relay which actuates the timers, the valve relay, and the valve. One timer (range .06 to 1.2 seconds) is set for oil admission time. The other timer (range, .6 to 12 seconds) is set for the interval between admissions. Foam breaker is added until the foam subsides. An indicating light is mounted in a conspicuous place to indicate when the magnetic valve is open.

The above system has been very effective.

Sugar End Controls

The principal controls used in the sugar end consists of Brix controllers on the intermediate and high green tanks and temperature controllers on high green, intergreen, standard liquor, low melter, and minglers.

We have installed Webre pan circulators on all our intermediate and raw pans with Webre's boiling point rise meter, which consists of an absolute pressure manometer and a thermometer placed in the massecuite. We have also installed contact-making Esterline Angus wattmeters on the pan circulator motors as originally conceived by Webre. The wattmeter is used to control an air-operated valve on the juice in line. All our pans at all our factories have absolute pressure controls on the condensers.

We would evaluate the pan controls as follows:

The circulators increase the heat transfer and allow the use of much lower pressures for the same heat transfer rate. The wattmeter is of value during part of the pan cycle as a density controlling method. The boiling point rise instruments provide the sugar boiler with a better mental picture of what is going on in the pan. The pressure control is a valuable means of holding uniform temperatures and is a valuable aid. The above controls have definitely been an aid in making us aware of the factors which affect sugar boiling and, in short, have definitely reduced the art of sugar boiling to a science. We have obtained our best results by utilizing the instruments as a guide.

Crystallizer Control

We have LaFueille crystallizers at three of our largest factories. We have developed the following control system for uniform cooling and heating: Tempered water is circulated from a tank through the crystallizer and back to the tank. The tank has an overflow line to the seal tank. Cold

water or hot water is introduced to the pump suction. A temperature transaire is mounted on the crystallizer with a dairy-type bulb mounted in the fillmass. The air is transmitted to and from crystallizer in a unique manner through telescoping Chiksan swivel joints. The second temperature transmitter is mounted in the discharge line from the pump. The controller consists of a proportional response plus reset controller with a differential element which takes the difference in the pressures from the transaires. The controller has a zero center chart with a plus 50 degrees for heating and a minus 25 degrees for cooling. The controller is synchronized at the 0 point for 10 psi. The water in and water out valves have valve precisors set for 10 to 2 psi and 10 to 18 psi operation. The transaire pressures are recorded on a temperature recorder. When the controller is set in the minus zone, the cooling water valve is opened. The crystallizer temperature is brought down in steps to suit the operator.

The above control system has been proven very valuable in providing a controlled rate of cooling, and in duplicating desired results.

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The 48 Inch x 30 Inch Continuous Automatic Recycling Centrifugal

ANTHONY H. STUHLREYER[1]

Since the advent of high speed centrifugals in the sugar industry some twenty years ago, there have been constant improvements in construction details by centrifugal manufacturers but little in the way of basic general new developments.

Now a basically different machine is available; a larger basket than is at present in general use and a degree of automatic operation ordinarily not attained.

All users and makers of centrifugals are aware of the desire for a continuous machine. In its ultimate form we conceive a centrifugal which would be started at the beginning of the campaign and would run continuously as long as massecuite is available to be purged, without an operator and with a continuous output of a constant quality sugar.

We all know that continuous machines approaching this end are in service in several industries; notably on salt, ammonium sulphate crystals, etc. Attempts have been and are being made to fit these machines into the sugar process but to date the success has been limited. In sugar, the viscosity of the mother liquor, the variations in crystal size and the large volumes which must be handled have created the difficulties which the continuous machine has not yet overcome. The attrition of the grain and the quality of the product established by the conventional batch centrifugal also are "stumbling blocks." We hope and expect that some day the ultimate in a continuous machine will be reached.

Progress cannot halt to await this ultimate goal. Concurrently with the search for a continuous centrifugal has come the actual development and utilization of the continuous batch machine.

The continuous batch machine is the conventional machine with which you are acquainted plus automatic loading, automatic plowing and automatic restarting of the next cycle.

The development of the machine evolved by stages so we will discuss the distinctive features in the order in which they were conceived.

The Automatic Plow

With conventional machines, the required low speed for plowing has been accomplished by several means; jogging the main drive clutch or motor, energizing the main drive motor with low frequency alternating current or by means of a small motor-driven worm gear reducer connectible to the main drive motor by means of a free-wheeling clutch. This last method of driving from a separate power source resulting in a fixed plowing speed was the only one which could be considered in connection with an automatic plow.

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[1] Sales Manager, The Western States Machine Company.

In the interest of safety we required that the plow be removed from the basket during high speed spinning. This complicated the necessary movements to be automatically accomplished and in looking for a solution we fortunately hit upon the idea of driving the basket in reverse for plowing. Thus it was no longer necessary to remove the plow from the basket during spinning. The plow shoe now trails the direction of spinning rotation and it is impossible for it to dig into the sugar wall. A greater safety margin is obtained than if the shoe rested on the curb top.

The slow speed drive for plowing called "Turntork" is a simple device. (Figure 1).

A worm gear reducer is mounted on top of the main drive motor with its output shaft vertical and concentric with the main motor shaft. The power is supplied by a 3 hp, 1800 rpm standard squirrel cage motor V-belt driven to the input shaft of the reducer. The combination of the V-belt reduction and the worm gear reduction give a final speed of 35 rpm for plowing.

The problem of connecting and disconnecting the gear shaft and the motor shaft has been most satisfactorily solved by the use of a Fawick air clutch (Figure 2). This device is composed of an inflatable rubber ring with friction segments on the outside. The ring is mounted on the gear output shaft. The friction drum on which the segments act is mounted on the upper shaft extension of the main drive motor. When the ring is inflated it expands and the friction segments contact the drum. When the air is released the ring contracts and the segments move away from the drum. Air is admitted to the ring through the shaft of the worm reducer. The torque output of the clutch coupling is readily adjusted by varying the air pressure. For our service we use from 30 to 40 p.s.i.g. The 3 hp driving motor is energized at the same time that air is admitted to the clutch. Interlocks are provided which insure against simultaneous operation of the "Turntork" and the main drive.

The "Turntork" drive was tried and proved with forward direction operation on many installations before it was adapted to reverse operation for automatic plowing.

With the plow remaining in the basket, the movements required for automatic operation were confined to an "In" and "Out" horizontal and "Up" and "Down" vertical motions (Figure 3).

The plow is of the square plunger type. The square plunger is used because it permits the use of flat bearing surfaces which are readily shimmed to maintain or restore the plunger rigidity so necessary for long screen life.

The plow shoe is rigidly bolted to the bottom of the square plunger and the plow tip is flexible because of its spring mounting.

For vertical movement a double-acting air cylinder is mounted parallel to the plunger, on the swinging housing of the discharger. The lower extension of the piston rod is fitted to the plow shoe just next to where it bolts to the plunger.

For horizontal movement a single acting air cylinder is built into the discharger housing. Compressed air causes the "In" movement while the "Out" movement is by spring return. An oil dash-pot retards the "In" movement so that the pressure exerted on the plow tip when entering the sugar wall will not cause the tip to gouge deeply but the pressure will be counteracted by the dash-pot and the tip will move slowly through the sugar wall to the screen.

The plowing function is controlled by the admission of compressed air through solenoid valves. These air valves are actuated either by timers or by the completion of a particular operation, which completion causes the next operation in the sequence to start.

Basket Bottom Closure

With automatic plowing came the need for a basket bottom valve mechanically operaated. For affination and raw sugar purging, some users have been content to use a loading cone on the spindle, which requires no movement. For the most part, however, and on white sugar in particular, it is essential that the basket bottom be closed during loading to prevent any spillage of massecuite into the sugar conveyor. For this requirement we have the air-operated conical basket valve (Figure 4).

The conical valve has a circular lip at the top into which the lifting hook engages. The hook moves from a vertical position with the valve seated through something more than 90° to reach the raised valve position. After engaging the valve lip the hook continues to move upward, raising the valve and cocking it with respect to the basket spindle. This cocked position provides room for the discharger to move down into the basket without interference and also leaves ample space to permit discharging of sugar.

The movement of the valve hook is accomplished by a double-acting air cylinder mounted vertically on the curb top. By a simple linkage system the valve hook raises as the air cylinder position moves down and lowers as the piston moves up. Air solenoid valves actuated from the automatic control cause the valve-lifting mechanism to function at the proper times in the centrifugal cycle.

The Automatic Loader

Experience in building and operating more than a hundred manual loading, automatic plowing centrifugals was attained before the first automatic loading centrifugal was built.

Several approaches to the loading problem were considered. Serious thought was given to measuring a fixed volume of massecuite in advance and loading just this amount into the basket. This was abandoned because of the complicated gear required in the mixer tank and because of cost. Timed opening was quickly cast off because the rate of flow through the charging gate varies with the head in the mixer and the fluidity of the massecuite.

Good practice requires a device which measures the charge in the basket and closes the gate in such a fashion as to reproduce in each succes-

sive charge the same volume of massecuite. This we have in the servomotor basket loader (Figure 5).

A pneumatic operated gate is used. The load in the basket is measured by a feeler which contacts the sugar wall and moves out as the sugar builds up in the basket. A servo-motor mechanism translates the movement of the feeler to a corresponding closing movement of the gate.

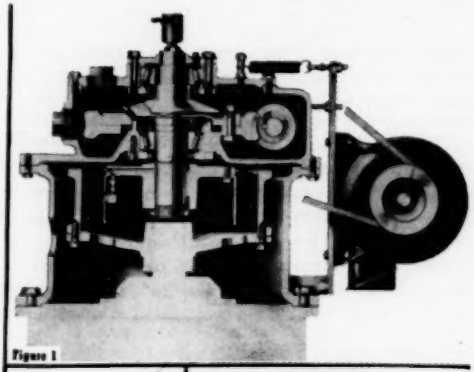

Figure 1

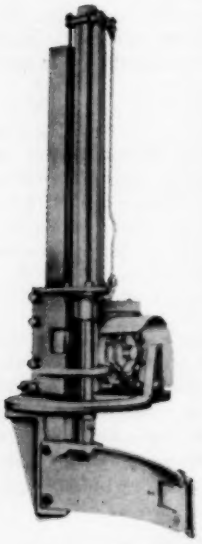

Figure 3

1-"TURNTORK" DRIVE
2-FAWICK CLUTCH
3-AUTOMATIC PLOW
4-AUTOMATIC BASKET VALVE
5-AUTOMATIC LOADER

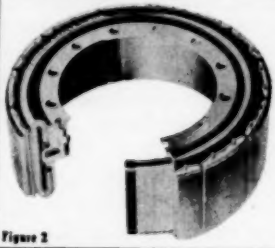

Figure 2

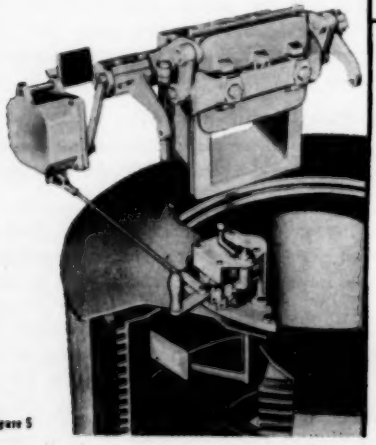

Figure 5

Figure 4

The feeler mechanism is mounted on the curb top. The servo-motor is mounted adjacent to the gate linkage. The movement of the feeler shoe is transmitted to the servo-motor by a lever. This movement causes an air valve in the servo-motor to control the air flow to the gate air cylinder.

When the gate opens the feeler shoe moves toward the basket wall to a position approximately halfway between the basket screen and the full load position. The loading gate at its open position now permits the loading of the basket to half load without any influence from the feeler shoe. When the basket is half charged, the sugar wall touches the feeler shoe and, as the wall thickness increases, the shoe moves "out." This "out" movement causes the air valve in the servo-motor to act, thereby moving the gate toward "shut" for a small increment of its total opening. As the sugar wall thickens, the gate continues its step by step throttling until the present desired basket load is reached. At this point the gate closes abruptly and the feeler shoe snaps to its maximum "out" position, well away from the sugar wall.

We now have all of the mechanical components for automatic operation of the various centrifugal functions. The automatic control must coordinate these operations to perform a complete centrifugal cycle and then repeat the cycle time after time.

The main drive motor is a two-speed generally 600/1200 rpm single-winding squirrel cage type designed for this particular service. Two-speed motors are used to reduce the power loss during acceleration and to provide regenerative electric braking to half speed. The automatic control combines the motor starting and stopping equipment with the process timers, limit switches, air and water solenoid valves, etc., to regulate the entire cycle and restart it after each completion.

We do not believe a detailed description of the control is relevant to the discussion. We rather believe our purpose would be better served if we describe what happens rather than how it is accomplished.

The Automatic Cycle

After completion of the plowing out of the previous charge, the following functions are performed:

The basket accelerates to approximately 240 rpm, the loading speed, and during this time the screen is spray flushed.

The gate automatically opens and the basket is loaded while rotating at the loading speed, shifting automatically from low to high speed after a timed interval, at approximately 500 rpm.

The gate closes when the preset load point is reached and the basket starts to accelerate toward top speed.

At about 600 rpm the first wash comes on for a 3-second interval.

Approximately 50 seconds after the closing of the gate the second wash comes on for a preset time, usually 7 to 12 seconds.

If syrup separation equipment is included, the separator trips shortly after the start of second washing.

At the end of the high speed spinning time, the high speed winding is de-energized and the low speed winding energized to regenerative brake to just about half speed. At this point the motor is de-energized and the air-operated mechanical brakes are applied, bringing the basket to rest.

When the decelerating basket reaches 50 rpm, the conical basket valve lifter starts functioning.

After zero speed has been reached, the "Turntork" motor and clutch are immediately energized and the basket rotates in counter clockwise direction at 35 rpm.

The plow now moves off the safety ledge and enters the sugar wall. After two revolutions of the basket, the plow moves down. When the plow reaches the bottom the tip remains against the screen for two revolutions and then moves half-out, remaining on the bottom for two more revolutions. This is done to get all of the sugar out of the basket.

The plow then returns up to its safety ledge. The "Turntork" is de-energized, both motor and clutch, and the basket is braked to rest. Simultaneously the conical basket valves seats.

When these actions are completed the motor restarts in forward direction on the next cycle.

Elimination of Trash Between Flumes and Slicers

J. L. Porterfield and E. B. Cowan[1]

Our subject title states in itself that we do have a trash problem.

It is our thought that we should cover the whole problem to properly show the origin and cause of the trash. To do this, we must necessarily go back to the preparation of the seedbed and planting of the beet seed.

Since the early 1940's, farming practices have continued to change rapidly. We call to your attention some of the following: Crop rotation; soil conditioning; planting practices; fertilization; mechanical blocking and thinning; irrigation, and mechanical harvesting.

Now we are ready to take the beets over our receiving equipment. A large percentage of our receiving stations, as we all know, are obsolete insofar as modern cleaning devices are concerned. It is true that various improvements have been made and many modern receiving stations have been built, but the greater percentage are about as they were twenty years ago.

Nearly every section of the beet growing areas has its own particular trash forming or handling problem. This may be rocks, clods, mud balls, weeds, grasses, excess beet foliage or various other foreign material, any of which present a difficult cleaning problem, and later on, if not removed, a very serious factory operational problem.

Some figures have been prepared to show typical beet receiving operations. One hundred forty-nine stations received 1,666,000 tons of beets in about a 60-day period. This figures out about 200 tons per station per day. However, averages do not always indicate a true picture. Some receiving stations handled less than 400 tons total, whereas the maximum handled over one station in a 60-day period was 140,000 tons. Several stations handled from 50,000 to 100,000 tons.

All of us know that a good cleaning job cannot be accomplished unless a thin layer of beets is permitted to pass over the cleaning equipment, and this is impossible when a receiving station is taxed to capacity operation.

The history of factory machinery obviously intended to mitigate factory problems goes back so far into the beginning of the industry that it becomes manifest that trash has always been with us to a lesser or greater degree.

Fluming

Most modern flumes are built with "run-arounds" or bypasses on their top edges, so that, when the flow of beets is stopped, the water will flow around the plugged portion.

The older type flumes without the bypass feature are frequently supplied with covers which are easily removed, one at a time, to allow the beets to slide into the flume.

When beets are transported by fluming, they receive considerable cleaning as encrusted dirt is washed off or softened so that it can be more easily removed in the beet washer.

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Many plants have found it necessary to install high pressure water jets, at relatively short distances apart, to periodically flush out large accumulations of sand, mud and small rocks. Others have found it necessary to use power-driven equipment to periodically remove mud balls and medium to large size rocks from the flumes.

Recirculation of flume water is a general practice. The recirculated water is passed through some type of screening system to remove beet tails and trash.

Beet Feeders

Beet feeders have been designed to even out the flow of beets in the header flume before they pass through the various pieces of trash removal equipment, as all operate more efficiently when fed at a constant rate. The rate of beet flow is controlled by regulating the speed of the beet feeder.

Trash Catchers

Trash catchers serve the purpose of removing loose beet leaves, weeds, grass and small untopped beets.

Mechanical trash catchers have steel bars having barbed hooks or sharp side projections suspended from an endless chain which travels in a counter-direction to the flumed beets and gathers the trash. As the hooks travel up and back over the flume, they are struck or bounced on fixed bars to disengage the trash, which is deflected by a baffle to one side of the flume.

Many plants have installed multiple trash catchers, some have added wheel drums to the trash catcher sprocket wheels and trash and drag hooks of various design have been tried for greater efficiency in eliminating trash.

Rock Catchers

Rock catchers of various design are used at most factories. Prior to mechanical harvesting it was not necessary to use rock catchers in the California territory. In the last six years it has been necessary to install rock catchers at some of the California plants.

Beet Washers

Two types of beet washers are common:

1. A large tank with satnd and gravel traps located under the perforated or slotted bottom. A large shaft with paddles turns within the tank to agitate the water and beets and in turn move the beets from the inlet to the outlet end.

2. A long narrow tank through which perforated flights are dragged by an endless chain system. This system moves the beets counter-current to the water flow.

Purpose of both types of washer is to remove dirt from the beets.

Trash Rolls

A series of horizontal or longitudinal rolls set on a declined angle serves the purpose of separating the beets from the water and also further eliminates dirt, sand and small rocks. These rolls, if not overtaxed, will also eliminate loose trash, and are of some help in stripping leafy material attached to the beet.

Picking Tables

Many of the plants are equipped with additional trash rolls between the discharge of the elevator and the picking table.

The beets are fairly well spread out and evenly distributed on the picking table belt, but are traveling at a fairly high rate of speed. The picking table man or men therefore only have time to hand pick such items as tin cans, pieces of wood, and large bunches of trash.

Magnetic Rolls

Magnetic rolls are usually placed at the discharge end of the picking table. They catch small pieces of magnetic material such as nails and wire.

Dead Knife Pocket in Slicer Drums

The dead knife pocket serves the purpose of a catchall for rocks and magnetic material which have escaped the previous trash moving equipment.

High Pressure Water Jets

High pressure water jets are used at the beet washer and trash rolls. The high pressure water removes adhering dirt and some attached leafy material from the beet.

Diffusers

While the continuous diffuser cannot be classified as a trash removing piece of equipment, it should be mentioned that excess trash does not seriously affect the mechanical operation of a continuous diffuser. Operation of a conventional battery may be seriously retarded when excess trash is encountered.

There have been many new efforts in recent years reattacking the problem of trash elimination at the factories, because agricultural progress, in its growing pains of modernization, has presented new problems exceeding the efficiency of the previously adequate trash removal equipment.

It is a generally accepted fact that while extreme trash and dirt conditions can slow up a plant to 10 percent or more of capacity during such periods, the beets finally going to the slicers are usually mostly free of everything not attached to them. The solution to the untopped crown, with up to six inches of leaves and quite often a bolter stalk in the middle, has so far defied factory machinery and inventiveness.

With today's high cost factors, each plant must maintain a maximum rate of slice or else it will find its operations winding up in the loss column. The inclusion of trash or soluble material from trash, tops and crowns reaching the slicers materially affects our operations as regards extraction and production costs. In addition to this, most plants are using 2-4 more men per day to handle the trash now being removed by our present equipment.

As previously stated, our subject is the "Elimination of Trash Between Flumes and Slicers." For the purpose of opening the discussion, we have used the experiences of one factory, showing what it has done toward improving the cleaning of beets of rocks, mud, sand and trash.

At the "A" factory, during the period of war years, or between 1940-1945 with the increased mechanization of the beet harvest, it became apparent that something should be done to remove clods of dirt and rocks,

which were shipped in great quantities with the beets. The beets received by car and truck were so filled with material of all kinds that it was impossible to float into the factory more than 25 percent of the needed quantity to supply the factory capacity. A crew of twelve men working with shovels, poke poles and also using an electric-driven wench to drag a walking plow through the flume, made little or no impression on the settled clods, rocks and leaves in the bottom of the flume.

In the intercampaign season of 1945-1946 a gravity separator was installed. The separator consisted of a pocket below the bottom of the flume and was located immediately after the beet feeder wheel at the wet hopper. The pocket was made full flume width, about three feet long and three feet deep. The underflow water for the separation was furnished from a line connected to the wet hopper drenching pump. Enough underflow water was used to float beets but rocks, clods and other heavy material were allowed to settle to the bottom of the pocket. This pocket bottom was made up of $\frac{5}{8}$-inch steel bars, spaced about $\frac{5}{8}$-inch apart, hinged to form a dump gate. The gate or pocket bottom swung open at regular intervals allowing the material to drop into a drag, which in turn loaded the mud and rocks on a gondola car. The interval of dumping of the gate was controlled by a Reeves variable speed drive, and was speeded up if the quantity of material being removed was extremely heavy.

The first season that the separator was used the amount of mud and rocks removed averaged about twenty-five tons daily. The past season, mud and rocks taken from the beets at this point averaged about seven tons daily. Some of this reduction might be accounted for by the fact that in 1946 few cars were emptied at the wet hopper by means of the drenching pump, while the past season all cars were unloaded in this manner. It can be assumed that the drenching pump dissolves many clods; however, credit for the decrease in dirt is partly due to the improvements in harvesting and beet receiving station equipment.

In the same year that the gravity separator was installed, the Franklin Jig was remodeled. The Franklin Jig was located just ahead of the beet wheel and this location was maintained for the reason that it could better serve at this point when fluming beets from the beet bins. The revamping of the Franklin Jig was done by putting in slanting bars in the pockets, eliminating baskets formerly used. The rocks and other heavy material were settled into the pockets by pulsations of the plungers as before, such settled material being removed from the pocket by side flush gates. The rocks and debris were elevated to ground by means of a scroll and drag. Sand, rocks and clods removed at this point averaged about five tons in a twenty-four hour period. The advantage gained by remodeling the Jig was in the cleaning of the rock pockets. Formerly it was necessary to haul out the baskets for dumping. The employee would not haul up the heavy baskets more often than he could help doing so. Now the man had to only turn a valve wheel opening the flush gate. The pockets were kept empty and as a consequence no rocks went by.

Sand traps were located in the flume just ahead of the Franklin Jig. These traps were of the conventional type, five in number and with manually operated dump levers. The sand thus removed was shoveled from the

pit to ground level. Each twenty-four hour period approximately six tons of sand and rocks were hauled away.

From the gravity separator to a distance of about seventy-five feet down stream the main ditch was also used as a header flume for the beet bins. This section was particularly troublesome, filling up with mud and rocks and leaves until it was almost impossible to float beets. It was in this part of the ditch that the water jets were first installed. A four-inch pipe line was laid in the bottom of the flume, removing concrete, and repouring, so that the top of the pipe was flush with the ditch bottom. Nozzles having a 5/8-inch opening were placed about six feet apart pointing down flume. The back side of each nozzle was protected by a piece of plate to prevent trash hanging on and reducing the effectiveness of the spray. In like manner, nozzles were placed in the wet hopper and under the beet control wheel, about five feet apart. Approximately eleven or twelve nozzles were used on each section. The water was turned on only one section at a time using a 550-gallon, two-stage pump, which gave a nozzle pressure of about 100 pounds.

The flume was cleaned by using the sprays at pre-arranged intervals when the beets are cut off at the control wheel. Usually, about five minutes were necessary to clear the ditch. When beets were being drawn from the wet hopper, the sprays on the flume bottom were turned on. This procedure assisted in moving the dirt and rocks into the separator pocket.

An additional change made at the wet hopper which improved the movement of beets and dirt was the covering of the bars in the run-around flume by steel plate, allowing a four-inch opening at the lower part of the bars for the water to pass. The plate not only prevented the runaround from filling with trash, leaves and small beets, but actually gave the water more pressure to move the beets.

Sprays were put in each of the seven flumes under the storage bins from the header flume at a distance of about 120 feet, spaced 10 feet apart, pointing down stream. Before the sprays were put in it was impossible to operate at more than 50 percent capacity. Enough beets could be moved afterward to keep the factory at full capacity.

It cannot be presumed that any system of removing rocks, sand and mud is perfect; however, it is evident that since 1945 progress has been made. Improvements to the predescribed process such as added pump capacity and doubling the amount of flume sprays have been deemed desirable. Mechanical means of dumping sand traps and sand removal would better the work at the sand traps. Perhaps future ideas yet to be worked out will give a more complete removal of rocks, sand and mud from the flumes.

Mud, sand and gravel which remain attached to the beet must be removed in the beet washer and on the roller picking table. An ample supply of water has been used flowing in an opposite direction to the movement of the beets. As in most plants now in operation, space had not been allowed to provide for a beet washer long enough to remove all of the mud which adheres to the beet at all times. Mud and sand were dumped at regular intervals by the use of flush valves located below the washer screen.

Additional sprays at the roller picker with increased water pressure assisted in removing some mud and small gravel which were held by the beet roots.

The men at the upper belt picking table were placed under direct supervision of the knife station foreman. Many tin cans, a few rocks, wood

and trash were eliminated at this point, preventing knife changes and loss of knives. A magnetic pulley at this place is always very helpful.

Many years ago the only means of removing trash from the flumes was by hanging rakes (somewhat similar to the present Dalton rake), in the flume. One or more men attended the rakes, pulling them out and dumping them on the ground. This method, while crude, was quite effective at the time, and was continued in use until the Dalton weed catcher was installed. The Dalton weed catcher had rakes hanging on two chains, spaced as close as possible and not interfering with one another. The chains were driven by means of sprocket wheels, and moved counter-current to the flow of the water in the flume, at the rate of about 28 feet per minute. The overall length of this weed catcher was twenty feet and it was housed in a heated building which kept it free from ice in cold weather. It was found to be very important that the rakes not hang too deep in the water. The proper depth, or rather the depth at which the rakes caught and held the most trash, was such that they did not bear too much weight on the floating beets. The rakes discharged their load upon an apron by means of dragging their upper back side over angle irons set in a slanting position across the top of the Dalton frame. It was found necessary to have a man attend to the trash for the reason that many untopped beets were caught. They had to be topped by the attendant and returned tothe flume. Rough estimates were that seven tons of trash and leaves were hauled away from the Dalton weed catcher each twenty-four hours.

Most operators are agreed that the use of an additional weed catcher located in the flume below or above the present installation would assist in removing more trash from the flume. Mechanical means could be used for piling of the trash from the Dalton were it not for the fact that many untopped beets are mixed with it.

The roller picker which is located at the beet washer discharge removed many leaves and much grass. The roller picker was made of a series of knobby rolls, eleven in number, 5½ inches diameter, 36 inches long, set 6 inches center to center. The rolls were placed horizontally, but sloping seven inches from front to back.

The knobs on the rolls grabbed the leaves and grass, discharging them below and allowing the beets to pass. Sprays at this point assisted in washing the trash into the rolls.

A wider and longer picker would be of advantage, provided that there was space available for a larger installation.

Probably much more can be said and many more things can be done to eliminate leaves, trash, grass, mud, rocks and sand from the beets on their short journey from bins to slicers. In the future a near perfect job can be done in the removal of undesirable material from the beets; however, we must call upon the personnel in charge of harvest to assist us in the prevention of contamination of all kinds, especially of the untopped beets.

Discussion[2]

This discussion centered about three topics. The first concerned the removal of trash by means of weed pickers, particularly as to the results

[2] J. E. Maudru, Session Chairman, Chemistry and Factory Operation, Eighth General Meeting A.S.S.B.T., conducted a general discussion at the meeting after presentation of this paper. This is a summary of that discussion.

experienced in relation to the number of rigs used in the picker. The thought was developed that four rigs in the flumes for any picker were about as many as the picker could carry. Experience indicated, also, that the use of more short pickers gave better results than the use of long ones. This information is based on the observation that the rigs were filled when they got half-way along the flume.

The thought was expressed that the time given to allow weeds to get up out of the beets has direct bearing on the matter. The trash which is down in the beets can be caught more easily by a second catcher if sufficient time is allowed for it to get to the surface.

The second topic of discussion was related to rock catchers. It was explained that the control of water admitted to the rock catcher installed at "A" factory is accomplished by taking water from the drenching pump of the wet hopper and diffusing it up through the slotted gate. A six-inch valve is used, operated about one-quarter open.

At Billings, where up to 350 tons of rock per day had to be removed, the wet hopper was placed close to the factory. Made of metal, it was constructed with six pockets, arranged sideways to the flume, each of which is an individual pocket with flume at the bottom and with a steep slope. High pressure jets were installed from there into the factory. Beets are taken into the factory by a wheel, slowing down the beets and making the rock wheel effective. Inasmuch as two ten-ton dump trucks operate twenty-four hours a day, the comment was made that someday all the rocks will have been removed from the Billings fields.

Another expression from comparative experience offered a different style rock catcher for comparison to the wheel and open flume or the drag under the opening in the flume types. In this style, beets are put in the water of a flume up above the ground by means of a beet wheel. Beets and water are then discharged into a flat steel trough about ten feet wide, spreading the beets very thin in the water. In the bottom of the trough, riffles are placed. Following two of the riffles is a very small drag, three or four inches high. The drag is protected by the riffle immediately ahead of it so the rock will drop out of the riffle into the drag. There are two such arrangements in series. While most of the rocks are caught in the first set, the second set usually gets the rest of the rocks with very few rocks going into the slicers. It was noted that this style installation is used in an area where the rock quantities are not as severe as they are at Billings, but it takes care of the smaller quantity very well.

A third point of discussion concerned the actual removal of stones and mud balls, after such have been caught, in a continuous operation. One expression from comparative experience gave preference to the use of a sturdy drag conveyor which can remove and load the rocks into truck or car in one operation. If a wheel is used, a smaller one might have advantages from the maintenance standpoint over a larger one. However, with any wheel, there still remains the necessity of conveyor loading or hand loading the rock into trucks for removal.

The Corrosion Problem in the Beet Sugar Factory

E. B. Cole[1]

The corrosion problem in the beet sugar factory is not a new problem. It has been with the industry since the beginning. However, until the past few years we have not been too concerned about the damage which corrosion has inflicted upon the factory equipment.

Since 1947 we have increased the daily capacity of our principal factories by an additional two-thirds to three-fourths of the original capacity. Since that time there has been an alarming increase in the damage which has occurred to the equipment each year. We believe that the increase in corrosion damage is due directly to the increased slicing capacity and the methods which have been adopted to maintain that capacity.

Last summer we performed a major repair job on the evaporators at our Nyssa factory. We replaced tube sheets, portions of the shell plate, bumped bottoms, and tubes in the first three bodies of a quintuple-effect evaporator. This job cost almost twice as much as the original evaporator station cost when new.

We believe that it may be necessary to replace several more evaporator calandria before very long. It is, therefore, necessary that we find a satisfactory method of solving the corrosion problem. It appears that the problem is more pressing in the evaporator than at any other station. However, there are several pumps and pipe lines which are also subject to corrosion damage. The continuous diffuser requires a special study of the problem. In the sugar end the corrosion problem has been a serious one because of the ever present danger of contaminating marketable sugar with scale and corrosion products.

What is Corrosion?

Corrosion is defined broadly as the deterioration or destruction of metal by the electro-chemical or chemical action of the environment upon the metal. Erosion is defined as the deterioration or destruction of metal by a mechanical or physical action upon its surface. Both words are from the Latin rodere, which means to gnaw. Very often the loss of metal is due to a combination of corrosion and erosion.

Ordinary corrosion products are oxides, (hydrates), carbonates and sulfides. At elevated temperatures it is the oxides which are most frequently found, especially in the presence of moisture. The main driving force is the electro-chemical potential between the metal and its environment.

The primary reaction is as shown in Table 1.

Similar reactions apply to the formation of carbonates and sulfides.

Table 1.—Primary Reaction in Corrosion of Metal.

$Fe + 2H^+$	$\rightarrow Fe^{++} + 2H$	
$2H + \frac{1}{2} O_2$	$\rightarrow H_2O$	
$2H$	$\rightarrow H_2$	
$2Fe^{++} + \frac{1}{2} O_2 + H_2O$	$\rightarrow 2Fe^{+++} + 2OH^-$	
	$\rightarrow Fe_2O_3 + H_2O$	
	$\rightarrow Fe(OH)_3$	

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This type of corrosion can be recognized by the presence of rust or scale where the metal is exposed to the atmosphere in the presence of moisture. Such are the conditions which prevail in open tanks and around machinery and structural steel which is exposed to the weather or to heat and high moisture conditions. This is the most easily recognized form of corrosion and the most readily prevented.

When corrosion takes place inside of a closed vessel such as the continuous diffuser or the evaporators, we are not made aware of the damage as readily, nor is it as simple a job to prevent the corrosion damage. Where there is much movement of the process liquors or materials, the products of corrosion are being continuously carried away. In this manner there can be considerable damage from corrosion without an accumulation of corrosion scale to announce the fact. In fact, in certain cases the corrosion can proceed so uniformly and leave a surface so smooth that it is impossible for one to assess the extent of the damage without drilling holes and measuring the thickness of the metal remaining.

This type of corrosion is due to the interaction of the metal and its environment, the metal supplying the positive ions, the environment the negative ions to form an oxide, carbonate or sulfide film which if not disturbed would act to protect the metal from further corrosion damage. But due to the activity of the environment the scale or film is removed and the metal again supplies ions to the reaction in a continuous cycle of self destruction.

Another very interesting form of corrosion is that due to the stray electric currents which are set up when two metals having different positions in the galvanic series are subjected to an electrolytic environment. This is known as galvanic and stray current corrosion.

This form of corrosion can be detected quite readily in the evaporators by a pronounced grooving in the tube sheet around the ends of the tubes on the liquors side of the heating surface.

Bronze impellers in cast iron pump volutes suffer from this damage. Even a stainless steel impeller may be subject to considerable damage if it is piped up with a lead pipe line in the boiling out acid system.

Care should be taken in prescribing metals for corrosion service so that we do not set up an electrolytic couple which will suffer from accelerated corrosion damage. See Table 2 in order to obtain an idea of the order of the galvanic series.

How Can Corrosion be Stopped?

There are three courses of action open: 1. Change the environment so that corrosion is less likely to occur. 2. Protect the metal with a film of corrosion-resistant material. 3. Insulate the dissimilar metals from each other to destroy the electrolytic couple. Or pursue all three courses of action at once.

The treatment of boiler feed water to prevent scale and corrosion is a familiar example of a change in environment. The dosage of the diffuser with formaldehyde is another example. Another, but not so obvious, example is the practice of deareating boiler feed water, or deareating evaporator

Table 2.—The Order of the Galvanic Series of Metals.

Corroded End
(Anodic, or Least Noble)
Magnesium
Magnesium Alloys
Zinc
Aluminum 25
Cadmium
Aluminum 17ST
Steel or Iron
Cast Iron
Chromium-iron (active)
Ni-Resist
18-8 Stainless (active)
18-8-3 Stainless (active)
Lead-tin Solders
Lead
Tin
Nickel (active)
Inconel (active)
Brasses
Copper
Bronzes
Copper-nickel Alloys
Monel
Silver Solder
Nickel (passive)
Inconel (passive)
Chromium-iron (passive)
18-8 Stainless (passive)
18-8-3 Stainless (passive)
Silver
Graphite
Gold
Platinum
Protected End
(Cathodic, or Most Noble)

supply liquors. At the present time there is no practical method of changing the environment in the evaporators to prevent corrosion. In fact, the contrary course is followed. By using proprietary compounds, we have attempted to prevent the formation of scale. This has contributed considerably to the increased corrosion damage in the evaporators in recent years.

There is very little freedom in changing the environment in the process vessels, as the requirements of the sugar process must be served first.

The second course open is that of applying a protective film to the metal to prevent corrosion. There is a wide variety of materials to choose from. There are oil base paints, which may serve very well for ordinary rust prevention. This remedy is usually not too expensive. There are plastic paints which serve very well to protect metals under more severe conditions of corrosion. The cost of these plastics is only a little more than the best grade of oil paints. The use of plastic paints is generally limited to service at temperatures below 50° C. and also where the abrasion is not too severe. Most plastic films scratch easily. Rubber and some of the special synthetic rubber compounds can extend the temperature limit up to 65° C. and to conditions of moderate abrasion. Rubber is fairly expensive to

apply and is difficult and expensive to maintain. The only non-metallic linings which appear to be able to give satisfactory service up to temperatures of 150° C. and resist moderate to severe abrasion are fused glass and the baked phenolic plastic paints. More will be said about these later.

There is a wide selection of corrosion-resistant metal surfaces to choose from. There are the surface films such as the anodizing or the alodyne process for protecting aluminum. The surface hardening processes for steel such as nitriding or carburizing will also improve the corrosion-resistant properties of the steel at the surface. We can apply an integral clad surface which will protect the base metal, Alclad for aluminum and Stain-Clad, Ni-Clad or Monel-Clad surfaces for steel. We can apply a corrosion-resistant surface by electroplating or metal spray methods. Thin sheets of corrosion-resistant metals can be applied in the manner of wall paper, except that we use plug welding and continuous seam welds at the edges to make the sheets adhere to the base metal. For certain applications the vessel may be made of sheets or plates which are 100 percent of the corrosion-resistant metal.

Before proceeding let me point out that these corrosion-resistant metals protect themselves by acquiring a tough, very resistant, oxide film on the surface of the metal, thus protecting the base metal or alloy underneath. In order for stainless steel to develop its maximum corrosion resistance, it must be made passive by forming a tough oxide film by treating the surface with an oxidizing agent, such as nitric acid, sodium chromate or ferric sulfate in the form of a rinse or bath.

The third course of action is that to be used in preventing the damage which results from galvanic or stray current corrosion. If we can effectively insulate the two dissimilar metals from each other then we can prevent the completion of the electric circuit and thus reduce the chances of galvanic corrosion. An alternate method is to cover one metal completely with a non-conducting, corrosion-resistant material, thus preventing the completion of the electric circuit and the resultant galvanic corrosion. Still another scheme is that of deliberately sacrificing one metal in order to protect the more important metal. This last scheme is known as "Sacrificial Anodic Protection." The usual method is that of placing a magnesium anode in the vessel, thus allowing the magnesium to suffer the corrosion. This last scheme must be used with caution and only after careful study, otherwise, it may backfire and form a new set of couples which may localize the corrosion in another vital area.

Very often, when we find that some particular part or piece of process equipment is being made unserviceable due to corrosion, the immediate response is to replace it with one made of stainless steel. In so doing we merely reverse the couple; the part which formerly was anodic now becomes the cathode and the rest of the system becomes the anode and suffers from the corrosion damage.

Now that we know what corrosion is and know of the general methods for combating it, what shall be done about it? To make the problem specific, let us outline a method for protecting the evaporators from corrosion.

We shall assume that in order to assist in preventing scale formations we shall continue to use the protective colloids in the evaporators. We shall also assume that we do not have an adequate corrosion inhibitor available for use. Deareation of the thin juice is the only remaining device which can be used to alter the environment in the evaporators. We shall heat the juice to three or four degrees above the atmospheric flash point and allow it to flash into a covered vessel. The dissolved and entrained gases, mainly oxygen, carbon dioxide, sulfur dioxide and ammonia, are partially stripped from the liquor and carried from the vessel by the flashed vapors. This method of deareation has proven effective in decreasing the corrosion damage in the first effect due to the presence of dissolved gases.

Let's assume that the evaporators we are planning to protect are already installed and that there are no major repairs necessary, but that we wish to protect the vessels from corrosion.

A look at the non-metallic corrosion-resistant films shows us that only two are suitable, fused glass and the baked phenolic lining. A fused glass lining is out of the question because of the necessity of shipping the vessel to the vendor's shop for the job. This leaves only the baked phenolic lining. Of the metallic linings, thin stainless steel has the greatest merit. It is the easiest to work and the lowest in cost. Surface preparation to receive the stainless sheets is simple, requiring only a vigorous wire brushing. However, it is almost impractical to consider lining the surface of the tube sheet with stainless steel sheets. Furthermore, a passive stainless steel lining will rearrange the electrolytic couple so that the copper tubes become the anodes and thus become the victim of galvanic corrosion.

We have come to the conclusion that the most suitable lining for these vessels is the baked phenolic lining. We have had a considerable amount of experience with this material and are fully aware of its disadvantages, but believe that its superior corrosion and abrasion resistance offset the difficult and tedious job of applying it.

The preparation of the surface of the steel must be meticulous in every detail. Sand blast or shot blast must be used and every last bit of scale must be removed. Every crevice and corner must be cleaned. Then, before a new rust film can form, a temporary protective film must be applied. This job should be done in relatively small patches so that the sand blasting does not get too far ahead of the temporary primer.

When the whole of the surface is cleaned and protected, the first primer coat of phenolic is applied. Brush or spray painting is permissible, but it is advisable to use a brush to cover weld seams, or fill in crevices or cracks. After the first primer coat the paint is given a short bake at low temperature to drive off the plasticizers and harden the paint. A second primer coat and two finish coats are also applied in the same manner, each coat followed by a short bake. After the last finish coat is applied, the paint is given a long high temperature bake to fuse and set the lining. If alternate coats of paint are of a contrasting color it aids materially in obtaining thorough and effective coverage. To obtain the best results follow the instructions that come with the paint.

The baked phenolic lining will give almost unlimited service under any conditions that exist in any sugar factory process. If applied under the proper conditions, and if the work is thorough and careful, and if the job is planned properly so as not to waste labor, the cost of this lining will be materially lower than that of a stainless sheet-lined vessel.

In painting around the ends of the tubes, care should be taken that the phenolic paint covers the outside of the projecting tube ends. This will isolate the steel shell from the liquor and prevent the galvanic grooving which occurs in the tube sheet around each tube end.

If it becomes necessary to replace tubes the outside of the tubes at each end can be given a coat of phenolic paint and permitted to air dry for several days before being inserted in the tube sheet; after which a short high temperature bake will set the paint and fuse the paint in the rolled joint.

We feel that, even for a new vessel, there is considerable justification in using the baked phenolic lining instead of stainless steel.

Pump casings and impellers are ideal subjects for the application of a baked phenolic lining, as are thick juice filters, standard liquor tanks, acid and soda system tanks and pumps. Also, short lengths of flanged pipe and fittings can be lined with a baked phenolic paint.

For longer pipe lines with several turns, a new type of plastic pipe which is formed from a fiberglass reinforced thermo setting polyester has been found to be very practical. Its cost is very competitive, it can be used at temperatures up to 110° C., and any pressure up to 1,000 psi. It has high mechanical strength and is easily installed after a little experience.

We believe that it is no longer good business to ignore the damage which corrosion inflicts upon the metal of our process equipment and that we must solve the problem at once. We also believe after a careful study of the problem that it is possible to solve the problem effectively and economically. At this time two products which are relatively inexpensive hold great promise—the baked phenolic linings for vessels, pumps, parts, and fittings and a Fiberglass reinforced polyester pipe, for pipe lines which are subject to corrosion.

I believe that it would be of great benefit to the sugar industry as a whole if the several companies would exchange information relative to the corrosion problem and the methods by which each company expects to solve the problem.

Table 3.—Plastic Material Selection Guide.

	Temp.	Pressure (In order of lowest to highest)	Impact Str. (In order of weakest to strongest)	Price (In order of lowest to highest price
Hard Rubber	120°	Polyethylene	Hard Rubber	Polyethylene
Polyethylene	125°	Hard Rubber	Saran	Butyrate
Butyrate	130°	Butyrate	P.V.C.	Fiberglas
Polyvinyl Chloride	160°	Uscolite (Std.)	Butyrate	P.V.C.
Saran	170°	Saran	Uscolite	Uscolite
Uscolite	170°	P.V.C.	Polyethylene	Saran
Fiberglas	230°	Fiberglas	Fiberglas	Hard Rubber

Table 4.—Plastic Pipe Stocks.

Manufacturer	Trade Name of Product	Technical Name of Product
Krayloy Plastic Pipe Company, Incorporated	Krayloy P	Polyethylene
	Krayloy O	Cellulose Acetate Butyrate (Tenite)
	Krayloy D	Polyvinyl Chloride Unplasticized (P.V.C.)
U. S. Rubber Company	Uscolite	Copolymer of Styrene, Butadiene, Acrylonitrile
E. E. Mills	Saran	Vinylidene Chloride
Reflin Company	Fiberglas	Fiberglas Reinforced Polyester
American Hard Rubber Co.	Ace	Hard Rubber

Lactic Acid Fermentation in Beet Processing Juices

J. B. Stark, A. E. Goodban, and H. S. Owens[1]

Our first report (1)[2] to this group, in 1950, demonstrated that lactic acid is one of the major acidic constituents of some diffusion juices. A general composition study of samples from nine factories presented at the 1952 meeting of this Society (2), confirmed the presence of varying amounts of lactic acid. If the lactic acid is produced by fermentation, at least an equal amount of sugar must have been utilized by microorganisms. Because lactates are melassigenic and decrease the efficiency of crystallization (3) approximately one and one-half times as much additional sugar will be lost in the molasses. The formation of 100 mg. of lactic acid for every 100 g. of sugar (or 0.1 percent on sucrose) will mean a direct loss of $250,000 annually to the industry. Depending on the price of molasses, there will be an equal or even greater loss through increased molasses formation. The lactic acid concentration exceeded this value of 0.1 percent on sugar (1, 2) for most of the juices previously examined at this Laboratory.

Materials and Methods

The general method of sample collection and preservation has been described in a previous publication (4). The methods of analysis are also described therein (4).

Results and Discussion

The results of analyses of diffusion juice and juice from comparable cossettes show that most of the lactic acid present in diffusion juice is formed during the diffusion process (4).

Table 1.—Lactic Acid Content of Processing Liquors, 1952 Campaign (mg./liter at 10% Sucrose).

Factory	Location	Diffusion juice	Molasses
1	Alvarado, Calif.	145	1620
2	Betteravia, Calif.	290	3100
3	Brighton, Colo.	100	3000
4	Carrollton, Mich.	140	2490
5	Centerfield, Utah	110	2600
6	Clarksburg, Calif.	160	2970
7	Loveland, Colo.	130	3940
8	Manteca, Calif.	240	2750
9	Moorhead, Minn.	1185	3320
10	Rupert, Idaho	210	1480
11	Sidney, Mont.	600	3200
12	Toppenish, Wash.	30	1290
13	Woodland, Calif.	250	1740

Analyses of samples from the 1952 campaign (Table 1) showed contents of lactic acid in the diffusion juices similar to those observed in the 1951 campaign. It is apparent that the concentration of lactic acid is considerably greater in the molasses than would be expected from the amount in the diffusion juice. With the exception of the samples from factories 9

[1] Western Utilization Research Branch, Agricultural Research Service, United States Department of Agriculture, Albany 6, California.

[2] Numbers in parentheses refer to literature cited.

and 11, there is roughly a 10- to 40-fold increase of lactic acid in molasses. Part of the unexpected increase in the molasses may be due to fermentation in holding tanks before heating and liming. Fermentation losses during holding can probably be decreased by heating the juice to above 70° C. as quickly as possible after leaving the diffusers and by cleanliness in the holding tanks and other equipment.

Part of this increase in lactic acid is due to chemical decomposition of sucrose by lime. Lactic acid is one of the principal decomposition products (5) of sucrose in highly alkaline solution. Honig (6) referring to work by Spengler and Todt (7) states, "In a solution of sucrose with lime of pH 12, the sugar loss in 1 hour boiling under normal pressure was found to be about 0.5 percent." The sugar loss is about three times higher per one unit rise in pH. The minimal decomposition of sucrose (6) takes place at approximately pH 9. Losses at this pH are about 0.05 percent for 1 hour boiling at normal pressure. A decrease of 10° C. in boiling temperature reduces this loss to about 0.02 percent or less.

On the basis of a six-fold increase of impurities from diffusion juice to molasses, it appears that approximately 200 mg. of lactic acid per 100 g. of sugar in diffusion juice is formed during liming and subsequent treatments at high pH. This shows the importance of not exceeding pH 9 or maintaining a high temperature for a longer time than is necessary.

It was desirable to know the site of fermentation during the diffusion process in order to evaluate the application of preventive measures. Tables 2 and 3 present the lactic acid analyses of cell juices from Robert batteries and continuous diffusers, respectively.

Table 2.—Lactic Acid in Samples from Robert Batteries (mg./liter of Juice).

	Factory			
Cell No.	8 Sample A	8 Sample C	1	6
1	335	85	175	90
3	315	10	265	120
5	315	10	290	130
7	315	10	....	95
9	270	10	250	80
11	110	....	60	....

Table 3.—Lactic Acid in Samples from Continuous Diffusers (mg./liter of Juice).

	Factory	
Cell No.	2	13
1	400	250
4	195	....
5	....	277
8	175	280
12	95	350
16	70	345
20	....	140

Samples A and C in Table 2 are from the same factory. "A" represents the lactic acid production with low temperature battery supply water. The battery supply was at 53° C., only the head cells being heated. Juice temperature did not reach 70° until the fifth cell, with a maximum of 85-87° in cell 2. A second set of samples from this factory (not included in the table) showed essentially the same levels of lactic acid. "C" shows the effect of increasing the temperature of the battery supply water to 62° and heating the cells at the tail end of the battery to obtain a temperature of 67° in the last cell and higher than 70° in all other cells. Under these conditions, the juice taken from cell 3 and the others going toward the pulp end of the battery contained only 10 mg. of lactic acid per liter as compared to the earlier figure of 315 mg. per liter. The diffusion juice contained 85 mg. per liter compared to 335 mg. per liter found earlier. In all cases the juice is considerably cooled when it comes in contact with fresh beets in the head cell. Considerable fermentation must take place in this cell in all batteries. In the case of "C," probably all the fermentation takes place in the first cell with concomitant diffusion into cossettes. In subsequent cells the lactic acid is extracted from the cossettes. It appears that fermentation is more severe than is shown by the amount of lactic acid present in the diffusion juice, since some acid may be retained in the pulp.

The temperature of the samples from factory 6 were also higher than for factory 8, Sample A. The temperature for cell 9 was 69° C. with a maximum of 85° C. in cells 3 to 5, The lactic acid present in the diffusion juice was about the same as in factory 8, Sample C, but it appears that a larger amount was carried out in the pulp.

The two factories with continuous diffusers appear to have two different fermentation sites. Much of the fermentation at factory 2 (21 cells) takes place at the beet end, while at factory 13 (24 cells) the highest lactic acid concentration is found in the center of the battery.

The data in Tables 2 and 3 represent only momentary conditions in each cell in a continuous process. Although the batteries may be nearly in equilibrium with respect to sugar extraction, this is not necessarily true of lactic acid production. Lactic acid production may take place in varying amounts at several places in the system, while sugar is introduced only in the cossettes. The cossettes, the juice,or the cell itself may be heavily contaminated with bacteria capable of producing lactic acid. The juice and cossettes leaving this cell will have an effect on the cossettes and juices from the other cells. This effect will appear to some degree for a number of cycles, since some lactic acid is being carried forward with the juice while some diffuses into the cossettes to be extracted by the succeeding juice. For these reasons it is very difficult to locate precisely the sites of fermentation in various batteries without information as to the previous levels of lactic acid in the juice and pulp. The data presented, however, show that conditions for lactic fermentation must be favorable in the first cell under present operating procedures.

From the marked decrease in lactic acid production when temperatures of 70° C. or above are used in the diffusion battery, it is apparent that pasteurization is one method of decreasing lactic fermentation. This method

may offer disadvantages in factories operating pulp presses, particularly if the alkalinity of the battery supply water is sufficiently high to solubilize the polysaccharides in the beet cell walls. This would adversely influence operations throughout the factory besides decreasing the pressability of the pulp (8). Recent attempts to control non-yeast fermentations in breweries and alcohol fermentations have been fairly successful (9, 10). Strandskov and Bockelmann (10) report the control of gram-negative rods by polymyxin in concentrations of 0.005 mg./liter. If this antibiotic could be successfully applied in diffusion at this concentration it would be less expensive than formaldehyde.

The finding of so much lactic acid in diffusion juice raises the question of other fermentations. In at least two of the processing liquors, significant amounts of dextrans were found (2). Freed and Hibbert (11) report the formation by enzymatic synthesis of oligosaccharides and polysaccharide gums by the bacteria, yeasts, and fungi present on or in frosted beets. No doubt other products of different organisms could be found on closer examination so that a real problem for the beet industry exists and warrants further study.

Table 4.—Lactic Acid in Samples from Factory No. 8 at Different Collecton Times (mg./liter at 10% Sucrose).

Sample	Date of sampling	Diffusion juice	Molasses
A	9/7/52	240	2750
B	10/7/52	190	2290
C	11/17/52	70	1360

Table 4 presents the analyses for 3 diffusion juice and molasses samples that were obtained from the same factory at intervals of two or three weeks. Samples A and C are the same as those given in Table 2. When the amount of lactic acid is decreased in the diffusion juice there is a corresponding decrease in the molasses. There is approximately 1 to 1½ grams of lactic acid per 100 g. of sugar in molasses that is formed by other means than fermentation in the diffusion battery.

Table 5.—Comparison of Lactic Acid in Processing Juices (mg./liter at 10% Sucrose).

Factory	Diffusion juice	Thick juice	Molasses
1	145	220	1620
2	290	750	3100
8	190	430	2290

Table 5 compares the quantity of lactic acid in diffusion juice, thick juice, and molasses. It is evident that most of the increase in lactic acid after diffusion takes place before or during concentration of the liquor to thick juice.

Summary

A comparison of lactic acid concentrations has been made of cossettes, diffusion juice, thick juice, and molasses. Lactic acid is formed during diffusion, probably by fermentation, which may occur throughout the battery.

A considerable portion of the acid is formed in the head cell. Increasing the temperature of the battery supply water markedly decreases the lactic fermentation. The high concentrations of lactic acid in molasses indicate alkaline degradation of sucrose during defecation and carbonation.

ACKNOWLEDGMENT

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Lactic Acid in Sugar Beet Processing Liquors

HUGH G. ROUNDS[1]

Dr. Harry S. Owens and his associates in the Sugar Beet Section of the Western Regional Research Laboratory have recently made the beet sugar industry cognizant of the abnormal occurrence of lactic acid in some processing liquors. Dr. Owens and his group have also prescribed a suitable method for measuring lactic acid (1) (2)[2]. During this past campaign we have been engaged in an investigation of lactic acid at various points in the process in our factories, particularly Twin Falls. This paper is a summary of observations and conclusions.

The method has been found suitable and accurate provided the analyst uses the proper technique for micro-analysis. The precautions listed in the method must be strictly observed.

Extreme care must be exercised in sampling to avoid contamination. Sample lines must be thoroughly flushed out before the sample is collected. Containers must be sterile with provisions for sealing. Samples should be analyzed within a short time after collection or quick-frozen for storage. Tests on unpreserved diffusion juice at room temperatures indicated an increase in lactic acid content of 30 percent in four hours. One would expect this figure to vary widely depending on the diffuser conditions at the time of sampling. To prevent such an occurrence during the period from sampling to analysis or freezing, low-density liquid samples should be protected by a preservative at the time of sampling. The preservative used must be tested for non-interference in the method of analysis. Thymol crystals have been found satisfactory, and there are undoubtedly many others.

The presence of lactic acid in processing liquors represents a loss in recoverable sugar both directly when it is a result of sucrose fermentation and indirectly in the formation of molasses. Lactic acid can conceivably find its way into the process through many sources, but probably the principal known sources are from the beets themselves, the result of fermentation of sugars, and the result of the alkaline decomposition of invert sugar (3). This, plus the fact that the reactions in which lactic acid participates in the process are not yet fully understood, make it impossible to know exactly the losses suffered as a result of fermentation. Nevertheless, by keeping these points in mind while following the lactic acid throughout the process, the possibilities of such losses can be estimated.

In investigating lactic acid formation in our continuous diffusers, samples of both juice and pulp were taken from various cells in chronological order based on the retention time of the diffuser. The results were reported on the basis of equivalent amounts of juice and pulp in order that the sum of the lactic acid present in these constituents might be followed. One would expect such results, if accurate, to show the total lactic

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[2] Numbers in parentheses refer to literature cited.

acid leaving the diffuser in the diffusion juice and final pulp to be equal to or greater than that in juice or pulp in any cell within the diffuser, assuming that lactic acid, once formed, remained as such.

Our results, however, present a far different picture, as in every test[3] the amount of lactic acid leaving the diffuser was greatly exceeded by amounts measured within various cells of the continuous diffusers. This pattern was also shown in the results of tests on a Robert Battery where juice from a single cell was tested periodically while in service. Tables 1 and 2 show typical lactic acid data for Continuous and Robert Battery type diffusers.

The reason for this negative lactic acid balance is not known, though we have eliminated some possibilities. To determine the presence of an

Table 1.—Twin Falls, Idaho Factory. Silver Chain-type Continuous Diffuser.

	5 Hours After Formaldehyde Treatment					30 Minutes After Formaldehyde Treatment				
Cell Number	Sample	Lactic Acid mg per Equiv. wt.[1]	Sample	Lactic Acid mg per Liter	Juice pH	Sample	Lactic Acid mg per Equiv. wt.[1]	Sample	Lactic Acid mg per Liter	Juice pH
			Diff.					Diff.		
	Coss.	35	Juice	190	6.40	Coss.	25	Juice	155	6.35
3	Pulp	155	Juice	290	6.30	Pulp	128	Juice	225	6.30
5	Pulp	220	Juice	445	6.05	Pulp	174	Juice	290	6.30
7	Pulp	185	Juice	445	5.90	Pulp	198	Juice	315	6.30
9	Pulp	235	Juice	420	5.80	Pulp	203	Juice	305	6.25
11	Pulp	200	Juice	400	5.80	Pulp	171	Juice	270	6.50
13	Pulp	175	Juice	335	5.75	Pulp	147	Juice	220	6.45
15	Pulp	145	Juice	280	5.70	Pulp	99	Juice	160	6.50
17	Pulp	120	Juice	250	6.10	Pulp	70	Juice	150	6.65
	Final					Final				
19	Pulp	55	Juice	220	7.10	Pulp	33	Juice	65	7.40

[1] Weight approximately equivalent to a liter of juice in same cell.

Table 2.—Rupert, Idaho, Factory, Robert Battery Diffuser, Samples from Single Cell During Cycle.

Time Minutes	Sample	Brix	pH	Lactic Acid mg per liter or Equiv. wt.	Time Minutes	Sample	Brix	pH	Lactic Acid mg per liter or Equiv. wt.
	Cossettes			24		Cossettes			29
0	Juice	17.7	6.45	26	0	Juice	17.3	6.55	61
5	Juice	8.8	6.55	37	5	Juice	7.3	6.60	65
10	Juice	5.7	6.55	66	10	Juice	4.4	6.50	98
15	Juice	3.5	6.60	51	15	Juice	2.6	6.60	102
20	Juice	2.0	6.50	58	20	Juice	1.6	6.50	98
25	Juice	1.0	7.35	11	25	Juice	0.3	7.30	22
	Final Pulp			5	30	Juice Final Pulp	0.06	9.10	7
	Pulp Water	0.06	8.70	1		Pulp Water	0.00	9.10	2 1

[3] Refers to tests conducted at Twin Falls, Idaho Factory.

interfering substance, samples of pulp and juice were taken from various cells in the diffuser and the lactate content measured. Known amounts of lactate were then added to the samples and the amounts of lactate redetermined. The measured values agreed with the calculated values from 93 to 100 percent. It is not believed that an interfering substance is responsible for the balance discrepancy.

To determine the stability of lactic acid at diffusion temperatures two samples of juice were taken from cell No. 9 of the Twin Falls diffuser, this point being one of the highest in lactic acid content. Both samples were preserved and portions removed for immediate analysis. The samples, one in a sealed container and the other in an open container, were then placed in an oven and held at 70° C. Portions of each sample were removed for lactic acid determination every 10 minutes until 30 minutes had elapsed. The result was that the lactic acid was not reduced in either case during this period, but rather appeared to increase about 20 percent in both cases. The question of the disappearance of much of the lactic acid formed in the process of diffusion is as yet unanswered.

PH values in diffusion juices do not always correlate with the lactic acid content because of a constantly changing buffer capacity in the juice. Nevertheless, pH values determined at regular intervals throughout do indicate the general condition of the diffuser, and therefore can be used as a guide in fermentation control during diffusion.

The level of lactic acid was determined at various points of juice travel in the beet end. Results showed an increase in lactic acid content at first carbonation and again as it emerges from the thickener. The invert sugar content of the juice is greatly reduced at these points, indicating that the

Table 3.—Twin Falls, Idaho, Factory, Lactic Acid in Beet End Juices.

Sample	Test 1		Test 2	
	Lactic Acid	Invert Sugar	Lactic Acid	Invert Sugar
	(mg/100gm sucrose)		(mg/100gm sucrose)	
Diffusion Juice	88	1,038	106	911
1st Carb. Juice	172	324	121	442
Thickener Overflow	259	129	175	166
2nd Carb. Juice	273	108	187	202
Thin Juice	284	108	196	113
Thick Juice	269	205	193	280

increase in lactic acid content here may be due to the alkaline decomposition of invert sugar. From second carbonation to thick juice the lactic acid content of the juice appears to remain quite constant. Table 3 shows typical data from beet end samples.

Following the lactic acid through the sugar end at Twin Falls, we found no serious increases; in fact, our results indicate a downward trend from thick juice to molasses. Spot samples were collected on four consecutive days from various points in the sugar end and lactic acid determined as milligrams per 100 grams of sucrose. These results were averaged, and a factor—derived from the corresponding weekly sugar flow averages—was applied to give the results a weighted value. These results are shown in Table 4.

Table 4.—Twin Falls, Idaho, Factory, Lactic Acid in the Sugar End.

Sample	Lactic Acid (mg. per 100 gm. Sucrose) Average[1]	Corrected[2]
Thick Juice	225	225
Low Melter	260	66
Std. Liquor	164	303
White Pan	174	322
High Green	337	322
Intermediate Pan	350	314
Machine Syrup	911	292
Low Raw Pan	793	303
Molasses	1,570	202

[1] Average of 4 tests run on 4 consecutive days.
[2] Corrected to sugar flow for corresponding weekly average.

Our investigation has led us to the conclusion that our greatest fermentation losses are occurring in the diffusion process at Twin Falls and that the seriousness of this loss is not shown by the lactic acid content in the final diffusion juice. Only by a study of the entire diffuser can the magnitude of these losses be estimated. Increases in lactic acid in the juices during the carbonation processes must be attributed at least partially to the alkaline decomposition of invert sugar. Our studies failed to show fermentation losses in the sugar end of the process. Certainly care must be exercised in using the quantities of lactic acid present to estimate sugar losses caused through fermentation; nevertheless, we believe that this determination brings us a step nearer in making one of the "unknown" losses "known."

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A Bacteriological Investigation of a Silver Scroll Type Diffuser

MARGARET P. MOWATT[1], JOHN LANDYSHEFF[2], AND W. W. BLANKENBACH[3]

Acid formation has been a major problem in the use of continuous diffusers, since it causes inversion of sucrose and corrosion of the equipment. There has been very little research reported on this subject but it is generally recognized to be due to bacterial action, and most operators have used formaldehyde as a disinfectant to inhibit the growth of these organisms and thus maintain a satisfactory pH level.

This report presents the results of studies made on the Silver Scroll-type diffuser, which was installed at the Taber Factory in 1950. The work was designed to obtain information on the bacteriological conditions and their relation to the pH of the juice under varying treatments with heat and disinfectants. The preliminary survey was made in 1951, followed by a much more detailed study in 1952, and some specific check tests in 1953, all of which involved counting the bacterial population in samples taken from individual cells of the diffuser.

Culturing and Sampling

To accurately reproduce in the laboratory the particular conditions in each cell of the diffuser was obviously impossible, so arbitrary standard conditions were set up under which the bacteria could be cultured and thus have a common basis for comparison when counts were made.

A trial with Bacto Dextrose Tryptone Agar as a medium indicated that it supported the growth of a great number and variety of organisms found in the diffuser and this was used during this investigation, although a synthetic beet juice medium had been developed in case B.D.T. was unsatisfactory.

Because of the temperatures in the diffuser, it was assumed that the organisms would all be thermophilic and it was found most practical to use a humidified incubator maintained at 55° C. Samples were obtained from each cell or from the supply water tank as required and were immediately plated. Suitable dilutions were estimated for each sample so that after 24 hours incubation the colonies on duplicate plates could be readily counted.

Investiation into Methods of Bacterial Control

1. The initial investigation consisted of introducing various amounts of p-formaldehyde into the diffuser with the simultaneous application of steam until cell No. 13 reaches 80° C. Sampling was done one hour after the treatment.

In Figure 1, the comparative effectiveness of four types of treatment is shown.

A. 15 pounds p-formaldehyde in cells Nos. 11 and 17.
B. 10 pounds p-formaldehyde in cells Nos. 7, 13 and 20.
C. 10 pounds p-formaldehyde in cells Nos. 5, 10, 15, 19 and 23.
D. 5 pounds p-formaldehyde in cells Nos. 5, 10, 15, 19 and 23.

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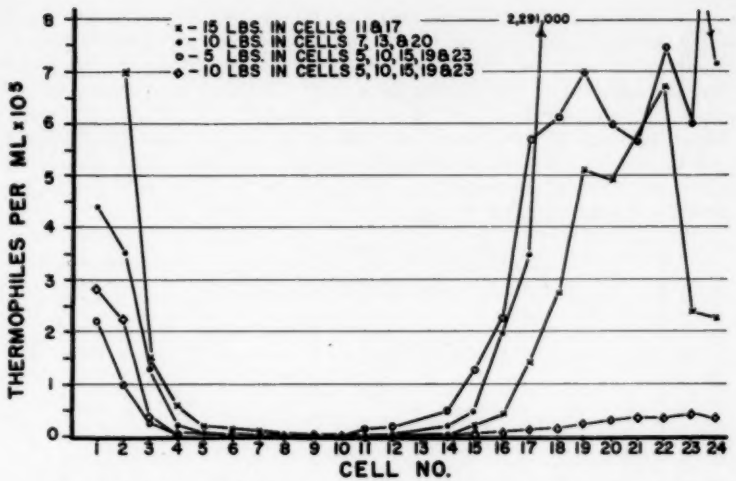

Figure 1.—Thermophilic counts one hour after treatment with various amounts of p-formaldehyde.

It will be noted that in all cases there was a definite reduction in bacteria from the first to tenth cells, with a steady increase to more than 600,000 in cell 22, except in case "C" where the bacterial numbers in the lower part of the diffuser were below 50,000 per ml.

2. To establish the amount of microbial activity under naturally occurring conditions, the diffuser was left untreated for a 12-hour period.

The counts obtained from samples taken after that time are shown in Figure 2. The heat in the upper deck appeared to have inhibited growth to some extent, but the juice in the cells of the lower deck contained about 300,000 organisms per ml. and these were mostly acid formers, which resulted in the pH of the juice being depressed far below average as will be seen in Figure 3.

3. To obtain information under conditions completely opposite to those of the last experiment, a complete disinfection of the whole diffuser was attempted by adding ten pounds of p-formaldehyde to each cell with a simultaneous application of steam. The effects of this treatment were evaluated by sampling 1, 4 and 8 hours after the addition and the counts are compared in Figure 2, along with those obtained in the preceding experiment.

It will be seen that after 1 hour the only high counts were in the last four cells and this condition was generally maintained after 4 hours, in spite of the constant introduction of bacteria by the incoming cossettes. The population increased very appreciably during the next 4 hours, particularly in cells 10 to 19, and the growth curve for the 8-hour samples approaches the one when no treatment was applied for 12 hours. It should be noted that the pH of the juice in cell 13 remained above 6.0 for 14 hours after the p-formaldehyde was applied.

4. The results of all these tests consistently indicated that the focal point of re-infection was in the lower deck, where the more moderate temperatures would encourage the growth of thermophiles. This suggested that the addition of p-formaldehyde toward the water end of the diffuser might be more effective, and when this was tried, by injecting the disinfectant into cell 21, the control was indeed superior. It was also observed that raising the temperature of the diffuser prior to addiing the p-formaldehyde increased the lethal effect and the pH of the juice was kept at a higher level for a longer period.

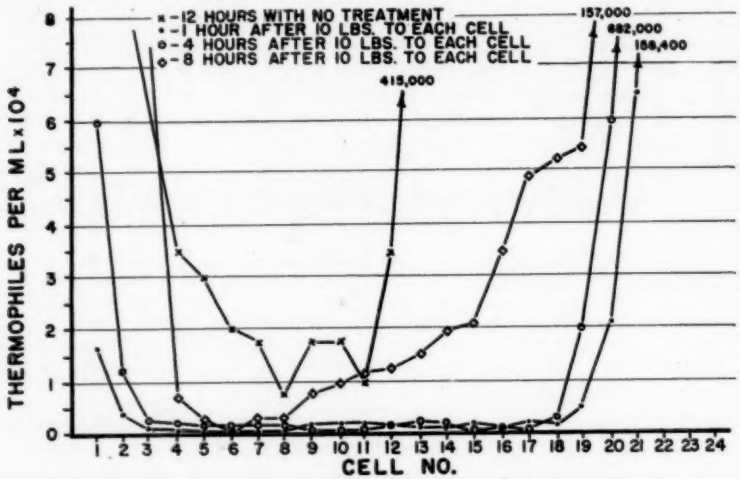
x - 12 HOURS WITH NO TREATMENT
• - 1 HOUR AFTER 10 LBS. TO EACH CELL
o - 4 HOURS AFTER 10 LBS. TO EACH CELL
◇ - 8 HOURS AFTER 10 LBS. TO EACH CELL
415,000
137,000
882,000
188,400
THERMOPHILES PER ML x 10⁴
CELL NO.

Figure 2.—Thermophilic counts after 12 hours without treatment and one hour, four hours and eight hours after adding 10 pounds p-formaldehyde to each cell.

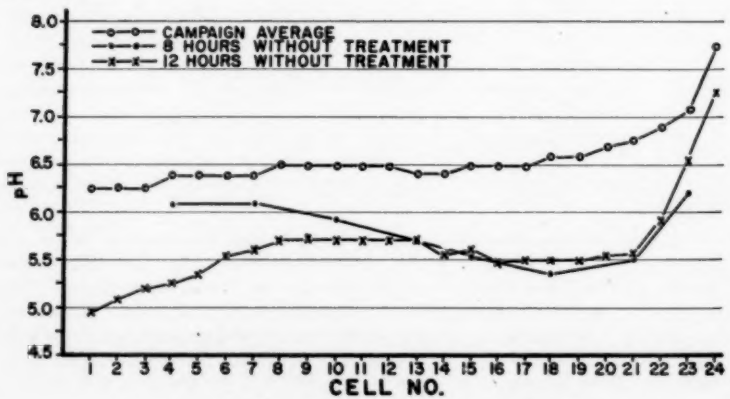

Figure 3.—pH values of the juice in each cell.

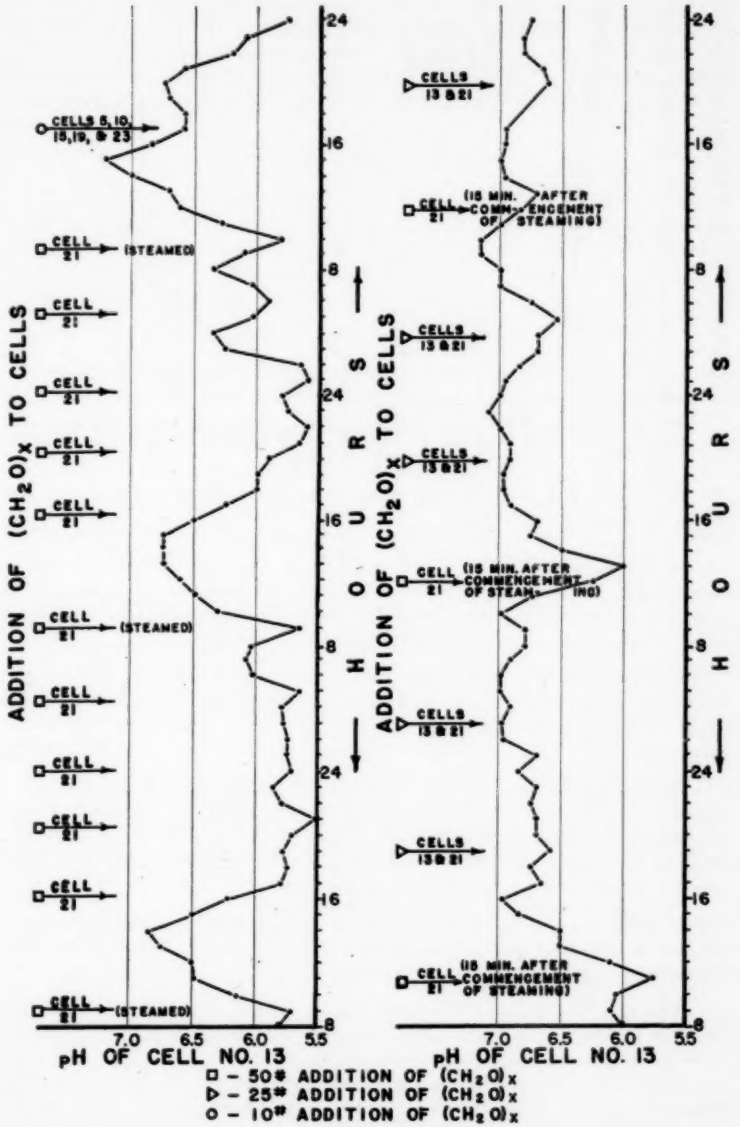
ADDITION OF $(CH_2O)_x$ TO CELLS
HOURS
pH OF CELL NO. 13
CELLS 5, 10, 15, 19, & 23
CELL 21
(STEAMED)
CELLS 13 & 21
(15 MIN. AFTER COMMENCEMENT OF STEAMING)
(NO)
(18 MIN. AFTER COMMENCEMENT OF STEAMING)
□ - 50# ADDITION OF $(CH_2O)_x$
▷ - 25# ADDITION OF $(CH_2O)_x$
○ - 10# ADDITION OF $(CH_2O)_x$

Figure 4.—Relation of pH of juice in cell 13 to p-formaldehyde and heat treatment.

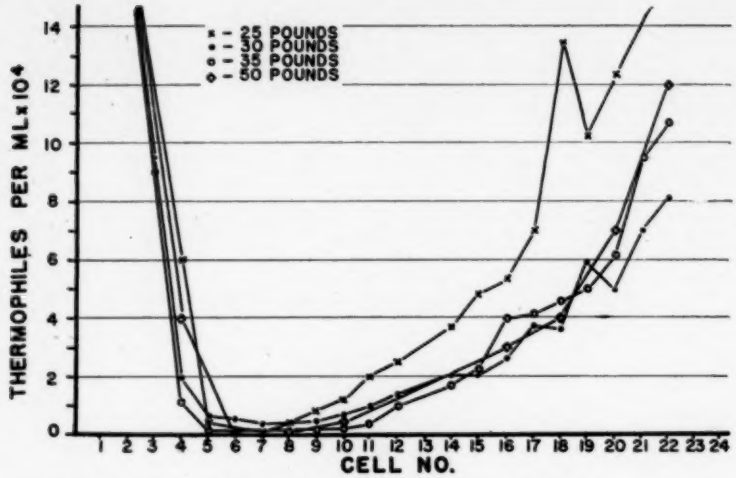

Figure 5.—Thermophilic counts one hour after adding various quantities of p-formaldehyde to cell 21.

In Figure 4, a plot of the pH of the juice from cell 13 illustrates these observations. It will be seen that, without steaming, the p-formaldehyde had little effect, but what was more important, the raising of the temperature before adding this material greatly enhanced its usefulness.

5. To establish the minimum amount of p-formaldehyde necessary to obtain effective control, a series of tests was undertaken in which quantities of 25 to 50 pounds were added to cell 21. These results are shown in Figure 5.

It is apparent that the application of 30 pounds or more was about equally effective, but the 25-pound quantity was less satisfactory. It was, therefore, concluded that a minimum of 30 pounds added to cell 21 would give the most economical results and this was further substantiated in 1953, when a re-check of the work was carried out.

6. The use of other disinfectants was also investigated from the point of view of economy and as an alternative in case of the development of a formaldehyde-resistant strain of bacteria.

The chlorination of the battery supply was tried in 1952 and the few tests for which time was available indicated a favorable response. However, in 1953, a more extensive trial, with residual chlorine as high as 10 p.p.m., failed to show any appreciable control of bacterial growth, and it was concluded that chlorination was not of economic importance.

Experiments with "Dowicide 31," a chlorinated phenol compound, showed it to be effective only when the temperature of the diffuser was raised. Because this compound appears to be mainly carried on the pulp,

it was found to give its best effect when introduced about cell 18, so that it would have a longer retention time in the last 6 cells. On a cost basis, the material could not compete with p-formaldehyde and its main value would seem to be as an alternative bactericide used in conjunction with p-formaldehyde, particularly if formaldehyde-resistant bacteria should develop.

Application in 1953

In 1953, the principles which were established from this research were re-checked. Counts made before and after disinfection followed the same pattern as in 1952, and it was found that adequate pH control could be obtained for periods of slightly more than 9 hours, if a regular routine of steaming and bactericide addition were carried out.

The following program for bacterial control was thus established:

Every 9 hours, the temperature of the diffuser is raised. Fifteen minutes after the steaming is started, 30 pounds of p-formaldehyde dissolved in water are introduced to cell 21 and the heating continued until the temperature in the center of the diffuser reaches 80° C. The diffuser is then allowed to return to normal temperatures.

This routine requires about one hour to complete, and results in the pH at cell 13 remaining near 6.8 for several hours, followed by a drop to about pH 6.2 before the next treatment is due.

Conclusions

From this work, we have concluded that the major growth of bacteria in the Silver Diffuser takes place in cells 19 to 24. The constant inoculation of the system by the incoming cossettes is of minor importance, as the bacteria from this source are largely destroyed by the temperature prevailing in the first six cells.

Effective control of bacterial growth, and hence the pH of the juice in the diffuser, is obtained by adding 30 pounds p-formaldehype, dissolved in water, to cell 21, about 15 minutes after a general increase in temperature is started, which is continued until the temperature in cell 13 reaches 80° C.

ACKNOWLEDGMENT

The assistance of Mr. Ken Corrado, who carried out the experimental work in 1953, is hereby acknowledged.

Studies of Lactic Acid in the Silver Battery

LLOYD W. NORMAN AND GUY O. RORABAUGH[1]

Introduction

Since the introduction of the continuous diffuser, the beet sugar industry has been confronted with a serious problem of bacterial fermentation in the diffuser process. Not only is sucrose lost directly by fermentation, but there is also undoubtedly some effect on juice purification and molasses production due to impurities introduced by the bacteria.

In recent work at the Western Regional Research Laboratory, United States Department of Agriculture (4)[2], a method has been developed for determination of lactic acid in beet processing liquors. This method has been employed in our work: 1. to determine the point of highest lactic concentration in the Silver chain-type batteries at the Carlton plant, Brawley, California, and at Sidney, Montana, and in the Robert battery at Santa Ana, California; 2. to provide a means of measuring actual sugar loss caused by bacterial action in the diffusion process; and 3. to measure the possible effectiveness of treatment of beets by a germicidal agent prior to slicing.

Lactic Concentration in the Battery

Samples of juice for analysis were taken from the juice ducts of the continuous diffusers and from the sample cocks on the Robert cells. A small amount of chloroform was added immediately, and the juices were cooled and quickly analyzed. All analyses for lactic were made by the method of Stark, Goodban, and Owens (4). This method calls for purification and separation of the lactic acid by ion exchange treatment and quantitative determination by the colorimetric procedure of Barker and Summerson (1).

Our results show that the lactic acid concentration in raw juice varies as widely as shown in Table 1. Earlier work (5) has reported concentrations from 82 to 1,610 ppm. (mg./L).

Table 1.—Lactic Acid Concentration (ppm.) in Raw Juice.

	Carlton	Sidney
Average concentration	149	98
Low concentration	9	45
High concentration	244	136

Within our company we have two continuous diffusers, one located at the Carlton plant, Brawley, California, the other at Sidney, Montana. Both are chain-type, Silver machines. We have obtained data on the lactic acid acid concentration prevailing in the various cells of these diffusers at certain times during the 1953 campaign.

In Figure 1 is shown a comparison of individual runs at the two locations. Of course, the conditions represent only that time at which the samples were collected. However, the curves obtained are typical of the results found in our investigations.

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[1] Chemical Engineer and Research Laboratory Manager, respectively, Holly Sugar Corporation, Colorado Springs, Colorado.

[2] Numbers in parentheses refer to literature cited.

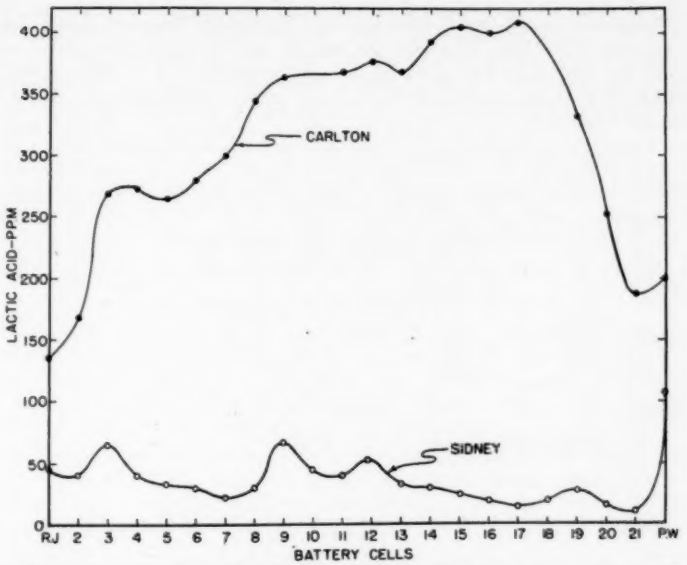

Figure 1.—Lactic Acid Concentration in Various Parts of the Silver battery at Carlton and Sidney.

The lactic concentration in the Carlton diffuser exhibited a marked peak in the centrally located cells, while no such peak was present in the Sidney battery. The average concentrations at Carlton were much higher than those at Sidney.

From Figure 1 it would be concluded that control measures at Sidney are more effective at the times investigated than those at Carlton. The battery juice temperatures at Carlton ran from about 65° C. on raw juice to a maximum of about 80° C. in cell 3 and back to about 65° C. in cell 21. At Sidney the corresponding temperatures were about 50° C., 60° C., and 40° C., respectively. On the other hand, addition of formaldehyde to the Sidney battery was approximately five times the amount used at Carlton. Thus it would seem that formaldehyde can effectively control fermentation even under temperature conditions quite favorable for bacterial growth. Needless to say, the cost of formaldehyde addition is a factor to be considered.

The geographic locations of Carlton and Sidney are such that extreme differences in climate are involved. Whereas at Carlton day-time temperatures above 100° F. are not uncommon during campaign, at Sidney much of the latter part of campaign can be in subzero wheather. Storage of beets at Carlton is seldom more than 24 hours, while at Sidney beets are often stored for 100 days or more. Neither the temperature in one case nor the long storage in the other is conducive to the best quality of beets. The amount of lactic found in Carlton beets averaged 50 ppm. That found in Sidney beets (late in campaign) was 64 ppm.

Since our Santa Ana, California, plant processes Imperial Valley beets in the spring, we had a unique opportunity to compare lactic acid formation in the Robert battery at Santa Ana with that formed in the continuous diffuser at Carlton at a time when both plants were operating on beets from the same area.

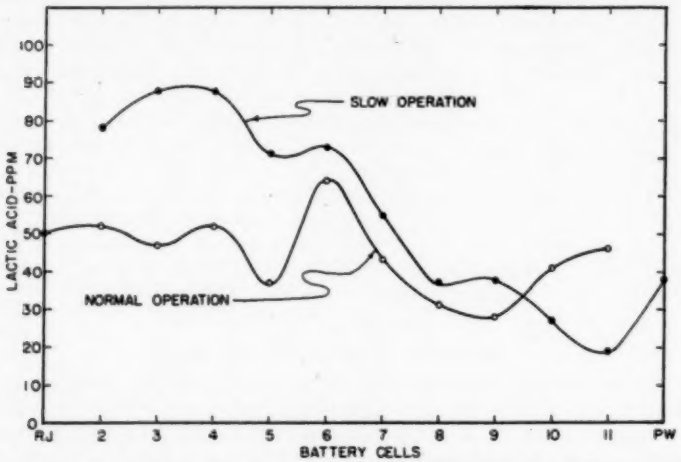

Figure 2.—Lactic Acid Concentration in Various Parts of the Robert Battery at Santa Ana.

Figure 2 shows the results obtained at Santa Ana when the battery was operating normally with about 45 minutes residence time for cossettes in the cell and when operating very slowly with about three hours hold-up of cossettes in each cell. The significant difference between these curves seems to be the peak in the curve for slow operation. During normal operation a relatively constant lactic concentration was obtained with little evidence of any lactic fermentation. Apparently the three hours' time during slow operation, along with somewhat lower temperatures, was sufficient to allow lactic fermentation to begin, as evidenced by the large increase in lactic with a maximum at cells 3 and 4. On the whole, lactic acid concentrations in the Robert battery bear out the contention that little or no fermentation takes place therein.

It was observed in our work that in those cases where a maximum lactic peak was found in the battery this peak fell into a rather narrow range of juice solids concentration of about 2.0-3.5 percent R.D.S. (Refractometer Dry Substance). This was true of the case where a peak was found in the Robert battery as well as those in the continuous diffuser. It would appear that the bacteria tend to thrive at these levels of solids concentration.

The relationship between lactic acid and pH in the various cells was an inverse one, as would be expected. The patterns of high lactic and

low pH followed each other closely during any one run, although the relative amounts of lactic could not be correlated with any given pH. It was felt that pH was a satisfactory control measure for factory operations provided changes in pH and particularly dips in the pH curve in the battery were carefully watched. Occasional checks of lactic acid levels should be helpful in factory control.

At Carlton in several of the runs made lactic was compared with reducing sugars obtained by the triphenyltetrazolium chloride method of Mattson and Jensen (2). Generally the reducing sugars decreased as lactic acid increased. This would probably be expected, since many bacteria attack reducing sugars in preference to sucrose.

Ratio of Sugar Lost to Lactic Acid Produced

If we can assume that the lactic acid produced is a measure of total bacterial activity and thus of the sucrose consumed by this activity, a ratio of the amount of sucrose lost to lactic acid produced would be of great value in calculating the sucrose losses in the battery. Such a determination is difficult since duplication of exact battery conditions is impossible and since calculation of loss of sucrose involves subtraction of two large values to obtain a small one. However, at Sidney several determinations of such a factor were made by analyzing fresh diffusion juice for lactic acid and true sugar (by single inversion), placing some of this juice in a sterile container, allowing it to stand for 24 hours at battery temperature (about 60-65° C.), and again analyzing for lactic acid and true sugars. The ratio was then determined from the differences of these two analyses. The results were ratios (by weight) of sugar to lactic of 0.81-4.44 with an average ratio of 2.14.

The figure is, of course, an arbitrary one, applicable with certainty only to the juices and conditions under which it was obtained. Such a ratio may vary from area to area, year to year, and perhaps even cell to cell within the battery. However, it does provide a figure which is in the right order of magnitude, as one mole of lactic produced from a mole of sucrose would give a weight ratio of 3.8 and a maximum of 4 moles of lactic from one of sucrose gives a ratio of 0.95, the average between the two extremes being 2.38.

As an example of the application of this ratio, let us calculate the average amount of sugar lost at Carlton per day under the conditions encountered. Assume that 3,000 tons of beets are sliced per day and that the draft on the diffuser is 130. The average lactic acid concentration in the entering cossettes is 50 ppm., and that in the raw juice is 149 ppm.

$$3{,}000 \times 2{,}000 = 6{,}000{,}000 \text{ pounds of beets per day}$$
$$6.0 \times 50 = 300 \text{ pounds of lactic acid enter in beets}$$
$$6{,}000{,}000 \times 1.30 = 7{,}800{,}000 \text{ pounds of raw juice per day}$$
$$7.8 \times 149 = 1{,}162 \text{ pounds of lactic acid in raw juice}$$
$$1{,}162 - 300 = 862 \text{ pounds of lactic formed in the battery}$$
$$862 \times 2.14 = 1{,}845 \text{ pounds of sugar lost per day}$$
$$\frac{1{,}845}{3{,}000 \times 2{,}000} \times 100 = 0.031 \text{ percent on beets}$$

Chemical Treatment of Beets

Since most of the bacteria which enter the battery come in on the surface of the beets, it was our thought that treatment of the beets with a germicidal agent before slicing might be of help in holding down fermentation in the battery. Several tests were made at Sidney to determine whether any of a number of chemicals might be promising in this respect.

Samples of 5 or 6 beets were taken from the picking rolls following the beet washer. The beets were cut in half longitudinally, with one-half being sliced by hand immediately and the other half being treated by immersion in the germicidal solution. Treatment was made at about 55°-60° C. for a two-minute period in solutions at the concentration recommended by the manufacturer. The treated beet halves were also sliced by hand and the cossettes produced in each case were placed in a sterilized container, covered with water, and allowed to stand at 60°-65° C. for 24 hours. The lactic acid content of the resulting juice was taken as a measure of the effectiveness of the germicide.

Table 2 shows the results of these tests.

Table 2.—Treatment of Beets with Germicidal Agents.

Germicide	Lactic Acid in Juice		pH of Juice	
	Untreated	Treated	Untreated	Treated
	ppm.	ppm.		
Chlorine compound No. 1	120	220	5.5	5.2
Quaternary amine	230	140	5.2	5.3
Wetting agent	140	115	5.3	5.3
Commercial detergent	320	345	4.9	4.8
Phenolic germicide A	540	270	4.9	5.3
Phenolic germicide P	345	20	5.1	6.1
Chlorine compound No. 2	350	245	5.3	5.3
Polymixin	240	230	5.2	5.0
Bromine	385	320	4.9	4.9

It will be seen that the quarternary amine compound and the commercial phenolic germicides appear to be quite effective in lowering the fermentation potential of the beets tested. Not only is the lactic acid reduced by these agents, but also the pH of the resulting juice is somewhat higher than the corresponding untreated samples. It must be concluded that treatment of beets by a method similar to that employed may hold promise in helping to reduce sugar losses due to bacterial action provided that other factors within the battery itself can be controlled satisfactorily.

Control of Fermentation in the Battery

At the present time there are two principal methods of control of bacterial action in the continuous diffuser: 1. maintaining a high enough temperature to discourage bacterial growth, and 2. addition of a germicide to the battery cells. Maudru (3) has shown that a good bacteria kill results if battery temperatures can be maintained at 70° C. throughout, but that a temperature of 80° C. is necessary to obtain complete destruction. The

addition of formaldehyde to the battery has proven effective, but in some cases large amounts are required, and such practice can be costly.

It is a well known fact that there are a great many locations within the continuous diffuser where cossettes can accumulate and lie stagnant. This held up material undoubtedly becomes an ideal breeding place for bacteria and a source of inoculation of the juice. We have found the concentration of lactic acid in some of these held up materials to be more than 2,000 ppm. as compared with about 50 ppm. in the original cossettes. Elimination of these stagnant areas is a most formidable task, yet it is felt that accomplishment of this will yield the most benefit in the control of fermentation in diffusion.

We list the following steps as necessary to control completely bacterial action in the continuous diffuser:

1. Elimination of stagnant cossettes.
2. Maintenance of battery temperature as high as possible consistent with satisfactory pressability of pulp and quality of raw juice.
3. Treatment of beets with an efficient germicide prior to slicing. Such treatment might well be advantageous, especially early in campaign, even if stagnant areas cannot be eliminated. Cost must necessarily be a factor in the choice of the proper germicide.
4. Addition of germicide to the battery stream when necessary, but only when other measures are not completely effective.

Summary

Data are given which show the lactic acid concentrations found in continuous and cell-type diffusers operating under widely different conditions. A determination is given of the ratio of sugar lost to lactic produced under arbitrary experimental conditions. Treatment of beets prior to slicing was shown to be promising in conjunction with other measures of control of fermentation in diffusion.

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Waste Water Treatment and Waste Disposal in the Eastern Area

J. E. LINDROOTH[1]

The beginning of the stream pollution problem by the sugar factories in the eastern area can probably be dated back to the early 1900's, when most of the factories were discharging all process waters direct to the streams, but it did not become a real problem until the Michigan State Legislature created a Stream Control Commission in 1929, with the power to compel industries to abate pollution. In 1949, another act of the Legislature changed the name of the Commission to the Water Resources Commission, giving it more power and a wider scope covering all the water resources of the state, and defining unlawful pollution as follows:

> "Unlawful pollution is any substance which is injurious to the public health or to the conducting of any industrial enterprise or other lawful occupation, or whereby any fish or migratory bird life or any wild animal or aquatic life may be destroyed; or the growth or propagation thereof be prevented or injuriously affected, or the value of lawfully taken fish or game be destroyed or impaired as a consequence of said pollution."

The first order of the Stream Control Commission against the sugar factories in the state prohibited the discharge of Steffens waste in any combination, into any stream or waters of the state, and limited the strength of other wastes combined, to 5 pounds of 5-day B.O.D. per ton of beets, based on the rated capacities of the plants involved. This order did not include Sebewaing because of its location on a large body of water, Saginaw Bay, which it thought could not be seriously harmed by the addition of our wastes. However, repeated complaints of fish killings near Sebewaing made it necesary for the Commission to issue a special order against the Sebewaing plant in 1949, making us responsible for any fish killing in this area during the operating season.

Our relations with the Water Resources Commission have been on a very cooperative basis, with the realization by them that they could not ask the impossible, and with our efforts to comply with their wishes always indicating that we are trying.

The foregoing gives you a brief outline of the legal aspect of our waste disposal problem, and now I shall attempt to describe the development of the process of treating sugar factory waste waters.

The Engineering Experiment Station at Michigan State College in East Lansing started investigative work on the treatment of beet sugar factory waste waters in 1933 with small pilot plants at Lansing and Mt. Pleasant, then used a large experimental plant at the Monitor plant in Bay City, with the cooperation of a committee sponsored by the Farmers & Manufacturers Beet Sugar Association, after which a quarter-size full scale plant was built at Monitor. This work resulted in the final treatment plant installed there and completed in 1939.

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The data collected during these years determined the classification of various wastes and their various strengths and volumes. They are described as follows:

Flume Water is classed as water used for fluming beets into the factory, including discharded beet washer water and water from the roll conveyor.

Pulp Water includes the water contained in the diffusion cells when they are dumped, plus the wash water necessary to clean the cells. It is all the water which can be drained from the pulp before pressing.

Pulp Press Water is the water separated from the pulp in the pulp presses.

Process Water is a mixture of the pulp water and pulp press water, and is defined here separately from the pulp water and pulp press water because, at some plants, the two waters are mixed and handled together.

Lime Sludge Drainage is the effluent from lime settling basins.

Their approximate volumes and strengths will vary with slope and condition of flumes, condition of beets, type of diffusion battery (bottom dump, side dump, continuous), and design of the pulp pit. Table 1 is a representative comparison of these waters.

Table 1.

Item	Flume Water	Pulp Water	Press Water	Lime Sludge	Total Waste
Gal./Ton Beets	2,640	440	250	75	3,405
B.O.D. ppm.	200	700	2,050	1,420	430
Total solids ppm.	2,060	1,290	3,740	3,310	3,140
Susp. Solids ppm.	1,460	210	2,560	450	2,215
B.O.D. Lbs./Ton	4.4	2.6	4.3	0.9	12.2
B.O.D. % Total	36.1	35.3	21.3	7.3	100.0

Steffens waste will contain about 10,000 ppm. of 5-day B.O.D., but has been omitted here because all Steffens houses in this area have been discontinued.

In the completed Monitor Waste Water Treatment plant, the condenser water was used for fluming beets, and the flume water was combined with the pulp water and pulp press water ahead of a Dorr drum screen. From there the water flowed through three grit chambers with chain-type sludge collectors on the bottom discharging onto a belt conveyor above the surface of the water, for grit disposal. This grit comes out of the collector at about 85 to 90 percent moisture. From the grit chambers, the water then flowed to the flocculators where it was mixed with Steffens waste as a coagulant. The sludge from the settling tanks was pumped into a pond, and the overflow of this pond was directed back to the system ahead of the flocculators. The effluent from the settling tanks went direct to the Saginaw river. Excess condenser water not used in the beet flumes bypassed the system and went into the river without treatment, and you will note that the lime slurry from the filter presses was flumed to a pond with no overflow during campaign.

This system worked satisfactorily, giving an average of slightly under the 5 pound of B.O.D. per ton of beets in each campaign after the plant

was put in operation. Recently, Monitor has installed a continuous diffuser and has discontinued the Steffens process. The basic operation of the waste water treatment system is practically the same, with the exception that pulp water has been eliminated and pulp press water is now used as battery feed water on the diffuser. As a flocculant, the operators now add a small portion of the lime slurry from their Oliver filters, and discharge the dust from a lime kiln dust collecting system into the main sewer. There is also a slight overflow from their house milk of lime tank which is also added at the main sewer. Another major change to this system is the fact that they now pump part of the effluent from their settling tanks back to the flume for use as flume water, providing about 50 percent of the water necessary for fluming beets to the factory. This serves to reduce their output to the river, and consequently keeps the B. O. D. within the limits of the Water Resources Commission.

Blissfield was the next plant to install a waste disposal system. Its system was a little bit different, in that the process water was used for battery washout, with the excess returning to the flume water at the beet wheel, after which all of the waste water was screened and flowed into a single thickener. The effluent from the thrickener was recirculated as flume water, and the sludge from the thickener and the excess effluent went to a series of storage ponds where it was retained for the entire campaign and finally discharged to the river during spring flood. A small amount of condenser water, or makeup, was added to the flume water, the remainder going direct to the river. The lime cake was flushed to the same series of ponds with pulp press water, and the Steffens waste was evaporated during campaign and shipped to a mono-sodium glutamate plant.

This system has been changed somewhat recently in that process water is now being chlorinated and used as battery supply water, similar to the operation at St. Louis, which will be described later.

Our first waste water treatment plant was installed at Alma in 1939 on a little different basis. Here we had a Dorrco bar screen through which flowed all of the flume water, into a large grit chamber. This grit chamber measured 14 feet wide by 55 feet long by 7 feet average water depth and was designed large to accommodate excessive surges which we were aware of in the fluming system.

The effluent from the grit chamber was pumped back to the flumes, with a certain portion being diverted to a flocculator and clarifier. While operating Steffens, about 6 percent of our Steffens waste was added to the flocculator as a coagulant. The effluent from the clarifier was discharged direct to the river, and the sludge was pumped to our lime pond. Pulp press water was used for flushing out the lime cake, and pulp water was used for battery wash water. We had a means of supplementing the battery wash water with condenser water and also using condenser water for makeup at the beet washer. While operating Steffens, our Steffens waste was stored in a pond until after campaign and pumped back to the house for evaporation and shipping to a mono-sodium glutamate plant.

This system was not without its faults, and a considerable amount of difficulty has been experienced with it. While there have been a few years that we have been under the 5 pound B.O.D. limit, our average is not

worth bragging about. The Dorrco bar screen was not adequate for handling the volume of leaves and tails in the system, and it was necessary for us to add a scraper type of bar screen with wedge-shaped screen bars about ⅜ inch apart. The last year Alma operated, pulp was found in the main sewer to the river, and no one could tell how it got there. Since discontinuing Steffens, we have added milk of lime to the flocculator in quantities heavy enough to bring the pH up to about 11. Records at this plant indicate that this amounted to about .35 percent on beets.

The scheme at Lansing, no longer in operation, was similar to that at Alma, except that that part of the process water which was not used for battery washout or lime sludge removal, went to the flocculator and clarifier without being mixed with flume water. Here, we had foam trouble in the flocculator and clarifier and never were able to clear this up. During one year of the Lansing plant operation, we had an agreement with a municipal sewage treatment plant to return the process water to the city sewers, but this played hob with the sewage treatment plant and we were not allowed to continue.

At our Caro plant, we were fortunate in having a lot of property with good sandy soil on which we could locate our ponds. Here, we constructed a sand filter bed by burying field tile in rows about 20 feet apart under a sizable pond area, discharging to the river. Our first several years of operation included the discharge of all of our water to these filter beds without any treatment. We soon found that the capacity of the filter beds was not enough to accommodate all of our flume water, so we installed a pump at the factory for recirculation of flume water.

Recently our results were not so satisfactory so we added a means of recovering our pulp press water for use in flushing the lime cake to the lime pond where this water could be held for the campaign and released during the spring high water. This has improved our operation at Caro so that we are well under the 5 pound per ton B.O.D. limitation.

Our system at Croswell involves mainly a series of ponds large enough to contain process water and lime sludge for the entire campaign. We are permitted to drain these ponds in the spring of the year when the river is in flood stage or nearly so. We discard our condenser water direct to the river, and run our flume water through a grit collector similar to the one at Alma, and pump back from the grit collector to the flumes. The excess from the grit collector is discharged direct to the river. Our coarse screen ahead of the grit collector consists of a Link Belt NRM 148 vibrating screen with a slot wire screen cloth with about ¼ inch mesh. We have experienced difficulty with fine grasses and hair-like roots wrapping around the screen wires and plugging the screen, causing the water to overflow the screen, and are still working on an answer to this problem.

At Carrollton we have a scheme similar to Lansing. The flume water is nearly 100 percent recirculated, being freshened with the addition of condenser water at the washer, with an equivalent amount discarded to the river at the end of the grit chamber. Pulp press water is screened over a 30-mesh vibrating screen and returned to the house for flushing out the lime cake. This water is held in ponds until the spring floods. Pulp water is also screened over 30-mesh vibrating screens before being returned to the

house for battery wash, with the unused water being discarded to a flocculator and clarifier, and thence to the river. We have foam trouble here. It forms at the entrance of the flocculator and covers most of the flocculator and clarifier and half of the yard before the campaign is over. Tests with several anti-foams were made this year, and we think we have found the answer in Nalco No. 71-D5 Anti-foam, which may cost us about $10.00 per day. In these tests, we found that, by keeping the pH in the flocculator at 11.3, a maximum floc would form which would settle in the clarifier if the foam were not present, holding too much entrained air in the clarifier water.

Sebewaing was the last of our plants to be affected by an order of the Water Resources Commission. After several years of trying to get by without having to install expensive equipment, and studying the changing conditions in Saginaw Bay at our outlet, we found that, when there is no ice on the bay, the wind will generally circulate the bay water enough to disperse our waste waters to the point that they are not harmful. But when the bay freezes over, circulation ceases and even a small amount of waste will deplete the oxygen content of the water so it will not support fish life.

We have developed a system of ponds and pumps which makes it possible to control our flow to the bay. Condenser water is not considered harmful, so it goes in a separate channel to the bay. Flume water is recirculated from a grit pond which is cleaned daily with our yard crane, and the excess water is pumped to other ponds where it can be stored or discarded to the bay as desired. Process water all goes to the lime pond and overflows to storage ponds where outlets can be opened or closed, depending on the condition of the bay. This year, we had a fisherman collect samples of the bay daily while the water was open, and were able to keep an accurate record of the dissolved oxygen. When it decreased, flow to the bay was lessened, and when it was high, all our waste went to the bay. In the last month of campaign, the bay is usually ice covered, and during this period, all waste water is held in the ponds. In the spring, when the ice is gone, the ponds are drained without damage to fish life.

St. Louis was troubled with problems similar to ours, and at first attempted recirculation of flume water without grit removal (coarse screens only). This resulted in a buildup of mud and B.O.D. in the flume water discard, and having insufficient land for ponding process water, the St. Louis plant finally installed a chlorination system.

Process water is pumped from the pulp efager tank, over a fine mesh vibrating screen, into a feed tank from which the flow is controlled to a chlorinating tank. Here, lime is added to keep the pH neutral, but I am told it will average about 6, and sometimes as low as 5 pH.

Chlorine is added through a bubble pipe by a Wallace & Tierman Chlorinator, manually regulated according to the residual chlorine in the battery feed water. The outflow from this tank passes through a Dorr thickener which happened to be left over from the Steffens operation, that allows retention time and, incidentally, settling time for removal of settleable solids. The sludge is drained back to the Efanger or to ponds, and the effluent goes to a head tank from which it is sent to the battery, one cell

ahead of the water cell. The overflow from this tank goes to the battery supply tank where it mixes with condenser water for battery feed. Excess water from the battery supply tank goes to the flume water ponds. Water from the vibrating screen tank is used for battery washout, with overflow being returned to the Efanger tank. Pulp press water and also evaporator seal tank water are added to the system in the Efanger tank. The bulk of this water is used in the flumes, with necessary makeup flume water pumped back from the flume water pond.

A similar system was installed at Fremont, Ohio, and at Blissfield. The Buckeye Sugar Company in Ottawa, Ohio, did the preliminary work on this system under the direction of Dr. E. A. Pearson, who made a study of "Sugar recovery and elimination of waste waters by chlorination in the beet sugar industry," for his doctorate thesis at M.I.T. He claimed that, by eliminating the discard of process water, the sugar in this water could be recovered. Laboratory figures after several years of plant operation indicate an increase in the amount of molasses produced, but no increase in granulated sugar. The principal advantage of this system is the elimination of the discharge of process water to the river.

Our Canadian cousins at Wallaceburg and Chatham have a system of ponding with which I am not too familiar, but I understand that, at present, the pollution problem there has not yet reached the force of law as it has in Michigan and Ohio.

Conclusions

The experience gained in more than fifteen years of attempting to avoid putting an excess of B.O.D., above 5 pounds per ton of beets, into the waters of our state, seems to indicate that reuse of as much water as possible is the best solution. Screening the larger particles out of the flume water and settling most of the sand is sufficient to condition flume water for reuse. Clean water is desirable for beet washers so the flume water settling chamber can be allowed to discharge only an amount equal to the water added at the beet washer. Pulp press water in most instances can be used for flushing out lime cake to settling ponds and be stored for the entire campaign. Pulp water can be cut to a minimum by reusing it for battery washout and addition to pulp pit if necessary, but adequate pond capacity for storage of the remainder for the campaign is preferred if available.

Treatment by coagulation and clarification can be adequate but requires attention and equipment. Condenser water is practically free of B.O.D. and can be discharged direct to the stream or any body of water without serious contamination.

Water Conservation and Process Water Utilization in the Beet Sugar Industry

J. E. BROWNING[1]

There has been an increasing industrial trend toward the conservation of process waters and the utilization of waste waters. This trend has been prompted by a number of factors. Increased population and industry have increased the direct use of water and the people attracted to man these industries have created an increasing demand for usable water for domestic purposes. In some areas there is direct competition between water for agricultural purposes and water for industrial and domestic use. This has resulted in new legislation and the formation of County Water Districts in some areas in California which are designed to regulate and control water consumption. In other areas numerous surveys have been made and are being made to serve as the basis of equitable allocation of water resources as well as to forecast the long range requirements of the community, county, area or state.

In the sugar industry areas principally affected, stimulation for water conservation and process water utilization has come from causes such as:

1. Lower water levels at plants supplied by deep wells.

2. Encroaching population near the factory site, making reduction of the nuisance value of waste disposal necessary.

3. Pollution problems of streams, bays and other common waters whose public use has increased to the extent that regulation is necessary.

Reduction in waste water production does not reduce the net output volume of solids and B.O.D. except in those instances in which special processes have been installed to utilize these solids. The dilution of waste does not reduce the poundage of solids and B.O.D. to be disposed of and is becoming a restricted practice, forcing the industry to adopt other methods. The handling and disposal of waste waters at many plants is an increasingly chronic problem.

Lowering waste water output is possible by several means, the two principal and most effective ones being the reuse of fresh water to the greatest possible extent and the utilization of process waters, with treatment if necessary, by reintroduction of as much of this water as possible into the factory processes replacing fresh water.

A third method is the disposal of some of the more objectionable solids to by-products plants as is done in the concentration of Steffen filtrate for ultimate use as a source of MSG. This removes one of the most difficult solids and B.O.D.-containing factory wastes, which have a high nuisance value at some factories, and passes the ultimate disposal problem to the

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MSG manufacturer. The latter, however, has made yet another salable by-product from this waste after extracting the MSG and has greatly alleviated his disposal problem.

Fresh water conservation by reuse is primarily accomplished by returning all condenser waters not needed for other purposes to a hot well and cooling same over natural or forced draft cooling towers. Fresh water from wells or other sources is usually added as makeup from a fresh water supply tank by overflow to the condenser supply tank or it can be added to the cold well or cooling tower basin and pumped into the plant as a common or single water supply system.

Water from the condenser seal tanks at somewhat elevated temperatures provides most of the diffusion battery supply water and the excess is returned to the hot well for cooling and reuse. Usually evaporator and pan condensates are used for boiler feed water and the excess hot water from these sources used for press wash and general hot water requirements. Any excess, including other condensates from plant evaporator and heating processes, goes to the battery supply where condenser seal water is used for makeup. In cases of temporary oversupply the overflow should go back to the cooling tower hot well and not to the sewer.

Another common water conservation practice is the recirculation of water used for fluming beets. Makeup water for fluming is drawn from the general water supply through the beet washer or is added to the flume water pump sump where there is no beet washer. Where a waste water treatment is used for the final plant effluent a system of pump sumps, with overflow in the proper order, preserves the quality of the flume water to some extent whereas in other systems all drainage waters from the plant processes, including Steffen houses and pulp driers, are screened and a portion equal to the input and overflows from the various sources is pumped out as final waste while the flume pump draws from this same source, recirculating this water through the flumes.

In the overflow sump system, Steffen waste, pulp silo underdrainage, lime and sludge pond drainage and other less desirable waste waters can be added to the sump ahead of the treating plant or to the final sump leaving the plant if no treatment is involved. The flume pump sump then is returned flume water plus makeup, and the percent of discard is regulated by the makeup and other fixed discharges from the plant such as final pulp cell water, battery washout water, etc.

A further degree of economy in fresh water requirements and a further reduction in final waste water volume has been achieved at a number of plants for several years by returning pulp separator water to a reserve tank to be used as battery washout hose water and pulp pit fluming water. All plants having conventional pressure batteries have this water disposal problem whether wet pulp silos or pulp driers are utilized for final pulp disposal. Continuous diffusers discharge drained pulp, thereby eliminating one source of waste water.

The next and latest step in the conservation of water is the product of necessity brought on by increasingly difficult disposal problems. This is

the utilization in the process of previously wasted process waters and is accomplished in a number of ways. There are several methods requiring some treatment of the water and at least one which reintroduces pressed pulp water into the diffuser without any treatment.

Another process utilization practice consists of treating pressed pulp water to effect a partial purification by the elimination of solids through floculation and settlement. The clarified water is then used in the Steffen process to make up cooler solution. In this manner, the sugar remaining in the water goes through further purification and is partially extracted as saccharate. The solids in this process can be discarded as sludge or, being high in protein, can be mixed with molasses going to a pulp drier, thereby becoming a portion of the dried pulp. There are other clarification processes utilizing chemical floculation, the treated waters being added to the diffusion battery as part of the battery supply. Some of these are the results of European development as well as work done in the American industry.

Each of the progressive steps in the conservation of water and the utilization of process water requires increasingly extensive plant facilities and, generally speaking, the extent of the effort in this direction is dictated by local conditions. In the case of simple reuse of fresh water the added plant facilities include considerable large underground piping for the return of condenser water seal tank overflow to the hot well, a large hot well to tower pump and auxiliary, a cooling tower and a cold water reservoir. In addition, pumps returning this water for reuse in the condenser system are required as are large underground lines, usually of some length, to handle the water to the plant condenser water tanks. If the cooling tower is a forced draft type there is an added major horsepower requirement in running the fan or fans of the unit. It is evident that there are extensive first costs and maintenance costs of facilities for this water conservation step.

The recirculation of flume water is a relatively simple and widely used method of cutting down the consumption of fresh water. It becomes more complicated when waste water treatment of the plant final effluent is incorporated. This requires a gravity collecting system for the factory main sewer or sewers with a pumping plant which in its most complex form does the following:

The flume water returning from the factory, plus selected drainage, is recirculated with a flume pump. The excess flume water plus the less desirable waste waters such as Steffen waste are pumped from the following compartment to the treating plant and the effluent from the treating plant flows to a collecting sump from which it is pumped to the disposal area, which can be a river or other body of water or prepared land for direct land disposal. This system involves several large pumps, a collecting basin with screens, and several hundred feet of usually large pipe line, and the power requirements are considerable.

The return of pulp separator water for factory purposes replacing fresh water generally used for battery washout normally requires many hundreds of feet of large pipeline, but if elevations are suitable no pumping is involved. Corrosion and maintenance are generally high on the tanks and lines used in the system.

The utilization of process waters has been accomplished in several ways but not without substantial investment in plant and some added power consumption. There is some confusion regarding the maintenance problems in the systems, but they are generally high because of corrosion. Some of these processes make claims for recoverable values which partially offset the operating costs, whereas in the other instances mentioned the only accomplishment is the elimination of a problem to meet local conditions with no monetary return.

It has been stated by Weckel (1)[2] that if all of the methods of elimination are used it is plain that the magnitude of the (waste) disposal problem of a beet sugar factory can be reduced. It appears entirely possible that by applying present knowledge the waste disposal load can be reduced to about 10 percent of that of a factory which practices no process water utilization and byproducts production such as the concentration of Steffen filtrate. No calculation has been made showing the results achieved by a typical maximum water conservation program but in many instances it has been established that the fresh water requirements and the flow of water from the plant can be reduced by as much as half or more, using combinations of the methods described.

Literature Cited

(1) WECKEL, W. O.
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[2] Numbers in parentheses refer to literature cited.

Factory Waste Stabilization by Aeration On Large Fields

E. H. HUNGERFORD[1]

Beet factory waste is characterized by several factors which add greatly to the problem of satisfactory treatment and disposal. Among these unfavorable factors are: 1. The large volume of effluent; 2. the large amounts of mud, limecake and other suspended solids; 3. seasonal operation of factories. A complete treatment of beet factory waste necessarily includes removal of suspended solids and stabilization of dissolved organic matter.

The sewage treatment commonly employed by municipalities involves removal of suspended solids in settling tanks and subsequent reduction to B.O.D. (biochemical oxygen demand) by passing the clarified liquid over trickling filters consisting of beds of rock over which the liquid is sprayed. Growths of microorganism build up on the rock in the filter, which under favorable conditions of temperature, pH and oxygen supply, effectively attack and destroy a large percentage of the organic matter in the liquid which trickles over the mass. Trickling filters capable of handling the wastes of a 2,000-ton sugar factor must be made very large, hence are costly to build. They are, moreover, only partly effective at the beginning of operation because considerable time is required to build up the active growth of microorganisms. A less costly solution of the problem of beet waste disposal is desirable.

Experimental Work

During the past two campaigns the Great Western Sugar Company has tested a modification of a procedure for waste disposal developed in Europe and used with some success at the Elsdorf sugar factory in Germany. At the Elsdorf factory, the waste is screened to remove roots and leaves and then passed through settling tanks to remove most of the mud. The thick mud is pumped to a storage area and the overflow passed through shallow ponds to eliminate most of the remaining suspended solids. Part of the clarified liquid is reused at the factory for fluming and washing beets. The remainder is passed over grass fields before it is discharged to the river. An arrangement of flumes and pumps permits diversion of the flow to a series of fields. In the usual operation one field is flooded for eight hours and then allowed to drain.

Experience at Great Western Sugar factories has demonstrated that settling ponds quickly develop considerable odor. It was decided therefore to attempt to carry out the Elsdorf plan without ponds. The installation was made at the Bayard, Nebraska, factory, where about 100 acres of gently sloping land (1,400 feet wide by 3,300 feet long), lying immediately below the factory were available. The installation was simple. The waste was conducted to the upper edge of the field by means of a ditch. It was pumped from the ditch to a flume 1,400 feet long, built on an earthen dike about 8 feet high extending along the upper edge of the field. During the first year the waste was discharged to the field from the flume through short steel pipes four inch in diameter, placed at 50-foot intervals in the side of the flume. These pipes rapidly became plugged with roots and leaves and it was necessary to have a man constantly at the flume to keep them

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open. The pipes were replaced by open ducts during the second season. The distribution of the waste to the field was accomplished threafter with little difficulty.

Results

The Bayard factory slices 1,900 tons of beets daily. It has a pulp dryer but not a Steffen house. Approximately 8 cubic feet of waste per second flowed into the aeration field. This waste contained all of the lime cake, flume and beet washer water, screened pulp water and pulp press water. Tests made by the Great Western Sugar Company's Research Laboratory and by the U. S. Public Health Service in 1949 show that the total B.O.D. in wastes from a beet sugar factory operating under these conditions amounts to 15 to 20 pounds per ton of beets. Results obtained in the tests conducted this year (1953) confirm those obtained previously. Data taken two weeks after the start of the campaign, and at three-week intervals thereafter, show 15 to 18 pounds B.O.D. per ton of beets sliced in the wastes discharged from the factory. The concentration of B.O.D. in the factory waste ranged from 787 to 600 parts per million. The B.O.D. concentration in the effluent from the field ranged from 143 to 320 ppm., indicating percentages of reduction of B.O.D. ranging from 80 to 40. The average reduction was about 70 percent.

Elimination of B.O.D. was more complete during the first part of the campaign, when the air temperature was about 63° F., than it was later when temperatures were near freezing.

It was observed that substantially all of the suspended solids were deposited within 100 feet of the inlet flume. One series of samples taken about 300 yards from the flume showed reductions in B.O.D. amounting to about 50 percent. It is probable that much of this reduction is accounted for by the deposition of lime cake and trash with the flume mud in the upper part of the field where it will remain to become part of the soil.

The field should have been levelled prior to the test, but in order not to disturb the natural grass it was left in its original state. Unevenness of the field caused considerable variation in the depth of water at different locations as well as in the rates of flow. It is estimated that not more than half of the total area was used effectively. The grass stems were quickly festooned with bacterial growth on those areas of field where the depth of liquid was sufficiently low. The grass served the twofold purpose of supporting bacterial growth and of increasing the area exposed to air.

Very little odor developed on the field.

Discussion

The waste disposal experiment at Bayard indicates that at factories where suitable land is available, removal of suspended solids and appreciable reduction of B.O.D. content may be accomplished in a single operation. Although the procedure is more effective in warm weather than in cold, considerable reduction in B.O.D. occurs even in freezing weather.

This method of factory waste disposal by itself may not be a complete solution of the beet factory waste disposal problem. It appears, however, that the B.O.D. discharged to the stream may be held below 5 pounds per ton of beets sliced at factories which do not have pulp silo drainage or Steffen waste.

Stream Pollution Abatment Legislation

L. T. JENSEN[1]

Legislation of any kind is usually brought on by a need as dictated by public opinion. The impetus behind present day stream pollution abatement legislation was the need for the conservation of our water resources. The whole supply of water is nearly constant from year to year, and, with ever increasing needs for water to serve population growths and industrial expansion, it is obvious that stream water must be kept at that quality necessary to satisfactorily serve downstream users. On the other hand, we are faced with the fact that streams are normally the only place in which liquid wastes can be discharged, whether they are of an industrial or municipal source.

It is nearly a foregone conclusion that there will be additional legislation enacted from time to time to prevent further degradation of our streams and to improve present stream conditions. It is unfortunate that this is the case, but we must realize that the person or persons who are polluting a stream do not usually suffer any damage to themselves from this action. It is the downstream users or inhabitants who suffer the consequences and they are the ones who bring the pressure on our legislators to enact laws to prevent impairment of stream quality.

The present status of the legislation relating to this subject will hereinafter be discussed under the two governments most active in this field, namely, Federal and State.

In the field of Federal government, the first comprehensive law enacted was the Federal Water Pollution Control Act (Public Law 845), which was passed by the 80th Congress in 1948. This Act was extended last year and is to remain in effect until June, 1956. It states that, "It is hereby declared to be the policy of Congress to recognize, preserve and protect the primary responsibilities and rights of the States in controlling water pollution, to support and aid technical research to devise and perfect methods of treatment of industrial wastes which are not susceptible to known effective methods of treatment, and to provide Federal technical services to State and interstate agencies and to municipalities, in the formulation and execution of their stream pollution abatement programs."

The Act provides that the Surgeon General shall:

1. Prepare or adopt comprehensive programs for the solution of water pollution problems in cooperation with the States, interstate agencies, municipalities and industries.

2. In developing the above programs, consideration should be given to all water uses, such as public water supply, propagation of fish and aquatic life, recreational purposes and industrial, agricultural and other legitimate uses.

3. Provide Federal research and technical assistance for any other agencies or persons.

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[1] District Superintendent, Great Western Sugar Company.

4. Encourage uniform State laws and interstate compacts.

5. Encourage cooperative State activities in the field of water pollution control.

6. Collect and disseminate information on water pollution.

7. Authorize Federal grants to State and interstate agencies to help them with their industrial waste studies.

8. Authorize loans to municipalities for construction of abatement works. (No funds were appropriated for this purpose.)

9. The Act also provided for Federal enforcement in connection with pollution involving interstate waters, where State control was considered ineffective.

Mr. Carl E. Schwab, Chief, Division of Water Pollution Control, Department of Health, Education and Welfare, Public Health Service, reported on the accomplishments and policies of that department at the January, 1954, meeting of the National Technical Task Committee on Industrial Wastes. The following is a summary of his remarks:

"Pollution data available from State and Federal sources on the country's 226 separate river basins have been assembled, analyzed and published in 15 drainage basin reports. Efforts are now being concentrated on the 146 interstate basins in order to get complete technical data so that a comprehensive plan can be developed for each of these areas.

"The availability of the facts regarding pollution conditions in most areas of the country, with a listing of the cities and industries responsible, has aided in bringing on increased public awareness of the problem. Organized local groups, such as business and civic clubs, women's clubs, health councils, conservation groups, sportsmen's organizations and the like, have become interested and are working with City and State officials to obtain public support for abatement projects needed in their own communities.

"There has been encouraging progress in the enactment of uniform State water pollution laws. The principles of a 'Suggested State Water Pollution Control Act,' as developed by the Public Health Service, have been used in new or amended legislation in eleven States.

"More progress is being made through interstate compact organizations in the development of uniform policies for pollution control on a regional basis.

"Pollution control is now being considered in resource development projects in the planning stages."

Regarding policies of the Federal water pollution program, Mr. Schwab stated that these policies present the purpose and direction of the national pollution abatement effort. Some are clearly defined in the Act, some are implied, others developed as required. Briefly outlined, these policies are:

"With respect to State responsibility, it is our policy to recognize, preserve and protect the primary responsibilities and rights of the States in controlling water pollution.

"With respect to Federal-State relations, it is our policy that such cities and industries creating pollution are responsible for its abatement. This policy stems largely from the law enunciated in legal de-

cisions involving the right of riparian owners to be protected against pollution. In areas governed by the 'common law doctrine' each riparian owner has the right to have the stream which flows past his property unimpaired in quality and undiminished in quantity. In States where the 'reasonable use doctrine' is in force, the reasonable use of a stream by a riparian owner may not be interfered with, and in western areas governed by the 'prior appropriation doctrine' the policy recognizes the accepted rule that the acquisition of water by prior appropriation for a beneficial use is entitled to protection.

"With respect to Federal-State relations, it is our policy that such relations shall be conducted on a cooperative, partnership basis, involving mutual respect and trust and full recognition of the respective individual rights of the partners, as well as their common responsibilities.

"With respect to Federal-Industry cooperation, our policy is to recognize industry as a key member of the team engaged in solving the national pollution problem, and to utilize industry's resources to the maximum extent in planning and execution of the pollution abatement program carried out under this Act.

"With respect to Interstate cooperation, it is our policy to encourage the fullest possible measure of cooperation among the States in their activities for the abatement of water pollution. There are now ten interstate compacts, with others in varying stages of negotiation or ratification. Informal regional advisory councils are also being encouraged.

"With respect to comprehensive program development, it is our policy that such programs must be prepared in cooperation with other Federal agencies, with State and Interstate water pollution control agencies and with the municipalities and industries involved. They shall be directed to eliminating or reducing pollution of interstate waters and tributaries thereof and improving the sanitary condition of surface and underground waters.

"A comprehensive plan for pollution control provides a means of focusing public attention on a certain stream or section thereof. It is the best means we have for giving citizen leaders, industries and others a basis for supporting needed remedial measures. It identifies the problem and suggests concrete and specific goals. The comprehensive plan has great value as a fundamental educational document. It shows what the people in the area will gain if the program is carried out. It tells where they are, in terms of water resource loss, if the program is not completed. It gives an estimate of the costs involved and states the project requirements in order to attain the quality objectives.

"These plans or programs, if they meet the requirements of the comprehensive program, are adopted by the Public Health Service as the official program, even if prepared by other agencies.

"With respect to Federal enforcement, our policy is to define, on the basis of investigations, surveys and studies, the areas in which interstate pollution is probably occurring; to leave the initial responsibility for enforcement with the States; and to exercise the full powers of Federal enforcement only after the efforts of the States have been exhausted, and then only with the consent of the State.

"With respect to reporting, our policy is to make available the facts on the national pollution problem, to report progress, and to provide related information, with the major objective of aiding the States, by demonstration and cooperation, in establishing means through which they may maintain effective reporting programs at the State level, where primary responsibility for the control of pollution rests.

"With respect to water pollution research, our policy is: 1. undertake research which will have the greatest immediate and practical effect on the prevention or abatement of pollution and which will primarily seek solutions to the most urgent problems existing at the time of consideration of projects, consistent with available resources; 2. maintain a satisfactory balance between short and long term projects, and between basic and applied research; 3. give preference to projects having the widest applicability; 4. not undertake research looking to the solution of problems of any individual industrial establishment; and 5. give support and aid to pertinent research conducted by other public and private bodies.

"The Act authorized grants of one million dollars annually to State and Interstate water pollution control agencies for the conduct of investigations, research, surveys and studies related to the prevention and control of water pollution caused by industrial wastes. Congress did not appropriate this money for this fiscal year.

"With respect to river basin development programs, our policy holds that water pollution control is a part of that program, and that water pollution aspects be considered from the initial planning stages of projects proposed under such programs.

"This work is being accomplished by cooperation and representation with other Federal agencies. This policy is being used in the development work underway in the Columbia, Missouri and Arkansas-White-Red River Basins and the New England-New York and Pacific Southwest areas."

In conclusion, Mr. Schwab stated that excellent progress had been made in many areas. However, some State agencies lack sufficient funds and personnel to allow full interstate cooperation. There are gaps in some of the basic data required, not only for delineating the problem, but for measuring progress toward achieving a solution. This is particularly true in measuring progress made by industry. Progress in abating municipal pollution is not satisfactory in terms of the vast amount of work required.

As members of industry, and more particularly as representatives of the beet sugar industry, we must now face up to facts that have been the outcome of the work of the U. S. Public Health Service under P.L. 845:

1. The amount of pollution caused by our industry is now well known and publicized and is pin-pointed as to location. 2. It is our responsibility to abate pollution to whatever extent possible. 3. Through the formation of Interstate compacts and the emphasis on uniform State laws, we will all be affected to about the same degree. 4. Although the public is well informed on the amount of pollution we are causing, it is not informed on the difficulty or cost to us to abate this pollution. We must therefore develop better public relations.

In connection with industry attitudes, two of our largest chemical companies have made public statements. The DuPont Company has stated: "Company policy dictates that no new pollution be created and that existing pollution continue to be abated as methods and equipment become available, until it reaches a point near zero." Union Carbide stated: "Carbide's management early adopted a policy of not permitting the construction of any new chemical manufacturing until the wastes could be properly handled without abusing the river. The company has adhered strictly to this policy."

At the present time we do not know what to expect in the way of Federal legislation when the present law expires in June, 1956. However, it could well be extended another four years, as was the case in 1952. Bills have been presented to Congress during the past few years requesting that capital investments made in connection with waste water treatment installations be given 5-year amortizations for tax purposes. Although these bills have not been enacted, industry in general is in agreement that some relief for these expenditures is necessary because they yield no financial returns and add a burden of operating costs.

As regards State legislation, there is a very wide difference in the kinds and types now in effect. The tabulation below gives the status of State legislation which uses a water quality criterion based on intended water uses, such as water supply, fish and aquatic life, etc. The following 20 States have water quality criteria established by law, rule or regulation:

1. Connecticut
2. Indiana
3. Kansas
4. Maryland
5. Maine
6. Massachusetts
7. Mississippi
8. New Hampshire
9. New Jersey
10. New York
11. No. Dakota
12. Ohio
13. Oregon
14. Pennsylvania
15. Rhode Island
16. So. Carolina
17. Tennessee
18. Washington
19. West Virginia
20. Wisconsin

The following 8 States have criteria being developed or considered:

1. Alabama
2. Arkansas
3. California
4. Florida
5. Michigan
6. Missouri
7. Oklahoma
8. So. Dakota

The following 9 States have been provided authority by their legislatures to adopt criteria, none yet developed:

1. Delaware
2. Illinois
3. Kentucky
4. Louisiana
5. Minnesota
6. Nevada
7. No. Carolina
8. Vermont
9. Virginia

The following 11 States have no provision for adoption of criteria by legislation:

1. Arizona
2. Colorado
3. Georgia
4. Idaho
5. Iowa
6. Montana
7. Nebraska
8. New Mexico
9. Texas
10. Utah
11. Wyoming

In addition, 4 interstate agencies or commissions have adopted criteria, and 3 have tentative criteria. To many of us the Missouri Drainage Basin

tentative guide for water pollution control activities should be of interest. The member States are: Missouri, Montana, Nebraska, Iowa, Kansas, Colorado, North Dakota, South Dakota, Minnesota and Wyoming.

In reviewing the present status of Federal and State legislation and the policies and activities being carried on in these categories, we can nearly predict what the future will bring in the way of waste water pollution abatement control.

1. In general, States will amend present laws or adopt new ones which will gradually bring about a basic uniform standard of water quality objective.

2. Enforcement of pollution abatement will be a State function, but Federal enforcement can be applied under the terms "interstate waters and their tributaries."

3. The present policy of Federal, State and interstate agencies in developing comprehensive plans for improved water quality in all areas will result in some sort of classification of waters as to legitimate uses. A list of uses such as:

1. Domestic water supply.
2. Shellfish culture.
3. Bathing and swimming.
4. Fish propagation.
5. Boating and fishing.
6. Transportation of wastes and navigation.
7. Fowl refuge and propagation.
8. Industrial water supply.
9. Irrigation and agriculture.
10. Aesthetic enjoyment.

4. The development of overall plans and classification of waters will be handled by a new State agency either wholly composed of representatives of various State agencies or composed in part of representatives of outside interests, such as industry, agriculture, municipalities, etc.

5. In some areas control will be applied to plant waste effluents and in other cases stream quality will be the criteria. The various factors of water quality which could come under control are:

1. B.O.D.
2. Chemical analysis.
3. Dissolved oxygen.
4. Coliforms.
5. Certain types of industrial wastes.
6. Floating solids, oil and grease.
7. pH.
8. Phenol.
9. Sludge.
10. Suspended solids and turbidity.
11. Taste and odor.
12. Temperature and color.

6. Some sort of financing will be provided for municipalities to use in building treatment plants.

7. Industry will be held responsible for solving its own pollution problems.

The papers which have previously been presented on this program give ample evidence that the beet sugar industry has made many gains in the field of water pollution abatement. However, much remains to be done before we can state that we have the means to accomplish the ultimate necessary degree of effluent quality that may be needed. The problem is to develop treatment systems which can be built and operated at a cost we can afford.

When you consider the amount of legislation and publicity that has developed in connection with water quality since 1948, it is evident that we cannot postpone our efforts to solve this problem much longer. We cannot defend ourselves against the accusation that we have polluted the streams.

When the time comes when the stream, into which one of our factories discharges its wastes, is made the subject of classification as to its legitimate use, we must, if possible, point out to the agency a number of pertinent factors. First, if a classification or criteria is set at standards we cannot hope to meet, that classification should be set instead on the basis of our industry's economic worth to the area as compared to the worth of, for instance, fishing. Second, before effluent control is imposed, a stream recovery study should be made to actually determine the effects of our wastes as compared to other wastes which may have been discharged into the same stream. This study should also determine what distance downstream our wastes are affecting water quality. Third, the public should be informed regarding the health features involved in municipal wastes as compared to ours. There is a growing tendency to evaluate industrial wastes on the basis of population equivalent, which often leads to erroneous public opinion. And, last, we should point out that we are doing something about the pollution problem and this must be done in deeds as well as words.

In order to accomplish the whole stream water quality improvement program a great many people other than industry will have to take corrective measures. Silt is one of the major pollutants of our streams and the reduction of this can only be accomplished by very exact soil conservation practices by farmers and ranchers, and these practices must be followed on the Government land areas containing forests. In other words, any person who discharges wastes of any kind, either liquid or solid, into a stream or any place where they can ultimately be washed into a stream, will have to be made responsible for abating these practices. At present, municipalities and industry appear to be the major offenders, but on analysis many individuals thoughtlessly add to the stream pollution problem.

Composition and Percentage of Marc in Some Varieties of Inbred Sugar Beets

HARRY S. OWENS,[1] ELIZABETH A. MCCOMB[1] AND GEORGE W. DEMING[2]

Recently, development of new varieties of sugar beets with improved processing characteristics has been emphasized to a greater extent than previously when increased disease resistance was the important factor. Marc content, however, has received little attention. To add to the knowledge of that part of the beet and to learn something about its genetic character, this laboratory and the Sugar Plant Investigations Division initiated preliminary work with 15 varieties of inbred beets. These were analyzed for sucrose, marc, pectin, araban, and galactan.

The importance of these components of the beet are summarized as follows. The marc content of sugar beets partly controls the volume of solution of basic lead acetate used in the Sachs-Le Docte method of sucrose analysis. Thus it plays a significant role in determining materials balance in the beet factory and in determining payments to the beet grower. The constituents of marc are important in controlling the maximum temperature at which the diffusers can operate. In factories which have pulp presses, the pulp is maintained in a pressable condition and the extraction of excessive amounts of materials, which may have deleterious effects on later operations, is prevented by keeping the temperatures low in the diffusers. Unfortunately, this may lead to fermentation and all its problems related to loss of sucrose and production of lactic acid, dextran and other harmful fermentation products.

The literature is replete with measurements of marc volume (1)[3], but the values range from 0.6 to 2.4 ml. per normal weight (26 grams) of beets. Insufficient study has been made of composition of marc (2). Because of the importance of marc content and its composition the investigation of these factors was undertaken.

Preparation and Analysis of Samples

Inbred beets were grown in plots at Fort Collins, Colorado, during the 1952 season. One sample of beet cossettes was collected from a factory in California, in order to have marc of a typical commercial variety for comparative purposes. The inbreds were rasped and composites of the pulp from nine or ten roots were made. Aliquots of the composites were used for sucrose analysis. Other aliquots were immediately frozen in pliofilm bags and air expressed to the Western Regional Research Laboratory. The frozen samples were kept at —20° F. until analyzed. The varieties are described in Table 1.

Enzymes in the marc were denatured by adding about 100 g. of weighed, frozen marc directly to 2.5 volumes of boiling 95 percent alcohol. The

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[2] Field Crops Research Branch, Sugar Plant Investigations, Agricultural Research Service, U. S. Department of Agriculture.
[3] Numbers in parentheses refer to literature cited.

Table 1.—Description of the Beet Varieties Used in this Study.

1952 No.	Origin	Generations
77	Cross; sugar and globe garden, short white beet, slightly pink skin.	G5 (sssg)[1]
81	Same as No. 77. Near sugar beet shape	G5 (sssgg)
89	Commercial	G8 (sggsssssg)
99	"Pioneer" commercial sugar beet	G10 (ssgssgsssg)
115	Probably "Fredricksen" sugar beet	G8 (ssgsssggg)
119	"Eagle Hill" (Danish) sugar beet	G5 (ssssg)
123	"Cesena" (Italian) sugar beet	G5 (ssssg)
124	"Hilleshog" (Swedish) sugar beet	G5 (ssssg)
144	Commercial sugar beet	G9 (o.p. sgsgsssg)
159	Commercial sugar beet	G7 (ssgsssg)
170	"Pioneer" sugar beet	G7 (ssgsssgg)
188	"Pioneer" sugar beet	G9 (ssgsgsgsg)
201	"Flat Foliage" sugar beet	G9 (sgsggsgsg)
238	Commercial sugar beet	G8 .....
246	"Flat Foliage" sugar beet	G10 .....

[1] Capital G and number indicate number of generations of known genetic history. "s" indicates space isolated or bagged plant; "g" indicates sib pollination.

marc was kept in boiling alcohol 10 minutes after thawing and then was extracted in a Soxhlet extractor. Five hundred ml. of 70 percent ethanol was used in the pot. The extractor held 330 ml; therefore, the concentration of the alcohol in the latter was never less than 80 percent in order to decrease dissolution of the araban. Not less than 15 extractions were performed but this number resulted from the convenience of overnight extraction and no significance should be attached to it. No arabinose has been found in the acid-treated extraction liquors, indicating that only a small amount of araban, if any, was lost during the extraction. No sucrose detectable by α-naphtol remained in the pulp. The extracted pulp was dried *in vacuo* at 60° C. overnight. Moisture determinations were run by another overnight drying *in vacuo* at 60° C. All results are calculated to moisture-free basis.

Pectin was determined by the McCready-McComb procedure (3). To obtain maximum extraction of the uronic acid-containing material, it was necessary to add 0.05 N alkali with 0.5 percent ethylene diamine tetracetate and extract for one hour before neutralization and addition of the pectinase.

Araban and galactan were run chromatographically after hydrolysis with acid for four hours. The procedure was to add 0.25 g. of pulp to 5 ml. of 1 N HCl in a centrifuge tube. Duplicates of each sample were run. The tubes were placed in a boiling water bath and tightly stoppered after reaching temperature. After a 4-hour period they were made to the original volume with water, if necessary, and centrifuged. The clear liquid was decanted into vials. The vials were stoppered and stored in the refrigerator.

Three 1-ul spots of the acid-hydrolyzed solution were spaced 1.5 cm. apart on S & S 507 paper. Standards containing arabinose and galactose at 0.5, 1.0, and 2.0 percent concentrations were applied on the same paper. The carbohydrates were chromatographed with Brown's raffinose solvent (4). After an overnight development, the papers were dried at 45° C. for 40 or more minutes, dipped into 3 percent aniline in ether, then into 3

percent trichloracetic acid in ether and dried at 80° C. for 15 minutes. In the earlier experiments, the reflection density of the spots was measured, using a 515 mu filter as suggested by McCready and McComb (5) of this laboratory. Measurements of galactose spots were more sensitive at 365 mu, however, and this filter was used for later experiments. Two-way chromatograms using t-butyl alcohol, formic acid, and water (6) and phenol-water in the second direction showed insufficient glucose to interfere with the galactose measurements. The standard deviation of 13 determinations of arabinose was 1.2 percent.

Time of hydrolysis with 1 N hydrochloric acid to obtain reproducible results was not critical for araban. The same results were obtained in 4 and 6 hour treatment. The galactan appears to be incompletely hydrolyzed at the end of 4 hours, inasmuch as higher values for galactan were obtained after 24 hours' hydrolysis. A compromise was necessary, because the yield of arabinose is decreased when a 24-hour period of hydrolysis is used. A 4-hour period of hydrolysis was chosen for this work because it gave the maximum yield of arabinose and was only 10 percent low with galactose. Because of decomposition of the free sugars during hydrolysis, the results for araban and galactan will be low. The actual loss, which appears to be less than 5 percent will be determined when sufficient quantities of these materials are available for test.

Results

Table 2 summarizes the data on marc content and the percentage of araban, galactan, and anhydrouronic acid in the examined varieties of beets. There are several items of interest. The correlation between marc content and sucrose content of the different varieties is remarkably good ($r = 0.69$) The explanation for the correlation is not clear. Although the marc con-

Table 2.—Analysis of Beets: Sucrose, Marc, and Water-Soluble Polysaccharide Contents.

1952 No.	Sucrose % on beet	Marc % on beet	A.U.A.[1] % on marc	Arabinose % on marc	Galactose % on marc
77	10.0	3.1	26	11	8
81	12.6	3.8	25	12	6
89	14.9	3.8	26	18	8
99	13.0	3.3	26	11	6
115	9.0	2.7	26	12	9
119	11.5	4.0	23	11	6
123	12.5	3.9	28	14	6
124	14.4	4.5	27	13	4
144	12.3	4.1	26	15	4
159	9.9	3.6	24	14	4
170	14.3	3.7	25	17	5
188	14.6	4.1	22	15	5
201	13.2	4.4	25	15	5
238	14.2	4.5	24	16	4
246	15.3	6.1	24	18	5
Calif. Commercial	—	5	21	22	8

[1] Anhydrouronic acid (a measure of pectin).

tent may vary by twofold, the percentage of anhydrouronic acid (a measure of pectin) varies but little. The cell wall structure is apparently constant with respect to this factor. The araban varies as widely as the marc content. There is a positive correlation between araban and sucrose ($r = 0.68$). Galactan percentage is low in the marc and was not considered sufficiently reliable for statistical analysis. No measurements are shown but a xylan or a complex of xylose and some other sugar was also noted in most of the pulps. This accounted for only 1 to 2 percent of the marc. Of the polysaccharides studied in this investigation only araban is indicated as a genetically variable characteristic. Present evidence indicates a positive correlation between sucrose content and araban; thus it may be impractical to decrease araban by breeding.

The marc content as determined indicates an average Sachs-Le Docte volume of about 176.6 ml., assuming no hydration of the pulp. Present indications are that the SLD volume may be higher than 176.6 ml. because of the presence of other optically active compounds and not because of unusual hydration of the marc.

The contribution of marc constituents to processing difficulties has never been systematically evaluated. Except for pectin, the physical and chemical properties of the polysaccharides are not sufficiently well known to predict their behavior during processing. Pectin is the best known and is a long chain molecule made up of galacturonide units (7). Some of the carboxyl groups are esterified with methyl alcohol while, in the case of beet pectin, some of the hydroxyl groups are esterified with acetic acid. There are present in pectin, in a more or less firm combination, arabinose, galactose, and rhamnose. It is also known that lime deesterifies and degrades pectin so that insoluble calcium pectate will form. The extent of the degradation is so dependent upon conditions that the findings of Finke (8) cannot be applied directly to American practice. Consequently, additional work in this field is needed.

The araban is apparently a low molecular weight compound (9) which will go through the defecators and into the thin juice. It may well be one of the gums reported to have deleterious effects on crystallization (10).

The galactan has not been studied.

Preliminary work by Goodban and Owens of this laboratory has shown that both araban and pectin are extracted much more effectively at pH 9 than at pH 6. The adverse effects on pressability of pulp, and sedimentation and filtration of first carbonation precipitate when alkaline battery supply water is used (11), may be the result of excessive extraction of these polysaccharides.

In summary, the marc content of the 15 different varieties of beets grown under the same conditions varied from 3 to 6 percent. There is a positive correlation between marc, araban, and sucrose contents of the inbred beets studied. Araban in the marc varies sufficiently among the varieties that it may be subject to control by the plant breeder.

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Determination of Sugar Beet Purity by Use of Mechanical Blenders

JULIAN R. JOHNSON[1]

The standard method of determining the apparent purity of beets has certain factors involved which introduce errors that are difficult to cope with when making an analytical analysis of elimination and factory operation.

To mention a few of the errors, we have: 1. the error introduced by pressure variations peculiar to the hydraulic press used; 2. condition of the press cloth both as to weight and sanitation; 3. the probability as to the degree of rupture of the individual cells or the degree of true representation of the expressed juice vs. the juice contained in the beet cells. The combination of these factors plus others make reproduceable results difficult and at times impossible.

In order to overcome these objections and to bring the analysis more directly under supervision the study of the use of the Waring Blender to replace hydraulic or manual presses has been made.

Table 1 represents the comparison between the conventional press juice and the blender extract. The press juice was obtained under as nearly ideal conditions as possible. Blending time in all cases was five minutes. The following data were taken from portions of the same lot of beets.

Table 1.

					Per 100 Sugar based on A.P.			
Sample No.	**A.P.**	**Dev.**	**S.A.T.P.**	**Dev.**	**Raff**	**Ash**	**Invert**	**Amino N.**
								(N x 7.5)
Press	85.7	.2	85.18	.11	.47	4.62	2.25	5.16
Press	86.1	.2	85.39	.10	.62	4.47	2.01	3.92
Avg.	85.9		85.29		.55	4.55	2.13	4.54
			Blended Samples					
1	85.3	0	84.65	.11	.62	4.22	2.10	4.66
2	85.6	.3	84.84	.08	.60	4.25	2.15	5.17
3	85.0	.3	84.47	.29	.51	4.26	2.13	4.50
4	84.8	.5	84.13	.63	.53	4.19	2.04	4.60
5	85.9	.6	85.42	.34	.44	4.12	1.99	4.19
6	85.4	.1	85.04	.28	.40	4.18	1.99	4.30
Avg.	85.3		84.76		.52	4.20	2.07	4.57

Blending 250 grams ground cossettes with 240 ml. dist. water.
Sample 1 was blended at room temperature.
Sample 2 was blended at 80° C.
Samples 3, 4, 5, 6 were blended after adding 240 ml. boiling dist. water to 250 grams of ground cossettes.

From the data on the blended samples itis found that all of the measured factors are in close agreement. This indicates that equilibrium is well

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established even when blended at room temperatures. In each case the weight of cossettes approximately equaled the weight of water. This mixture produces about a 9.0 Brix sample of sufficient volume to run all the analyses usually required.

The procedure adopted for our standard method of analysis is as follows:

Couple the blender through an interval timer so that after the allotted blending time the apparatus is automatically shut off.

Blend approximately 250 grams of ground cossettes with 250 ml. boiling distilled water for exactly five minutes ± 15 seconds. Separate the liquid from the pulp immediately either by using toweling or by vacuum with a Buchner funnel fitted with a filter cloth. Cool the sample to 20° C. and complete the analysis as soon as possible, using the refractometer and either wet or dry lead methods.

Table 2 shows a brief study to determine proper blending times.

Table 2.

Control Sample	A.P.	Dev.	Blended Sample	Blending Time (min.)	A.P.	Dev.	Blended Sample	Blending Time (min.)	A.P.	Dev.
Press 1	85.1	.2	1	3	85.1	.0	6	5	85.4	.1
Press 2	85.5	.2	2	3	85.2	.1	7	5	85.1	.2
Press 3	85.3	.0	3	3	84.8	.3	8	5	85.4	.1
			4	3	84.7	.4	9	5	85.3	.0
Avg.	85.3	.1	5	3	85.7	.6	10	5	85.5	.2
			Avg.		85.1	.28			85.3	.12
			Est. % Error 3			± .46%		5		± .16%

The relative percent error for a five-minute blending time is smaller than the error found in the three-minute period. For this reason the five-minute period is to be preferred.

This same method is applicable for rasped beets in tare laboratories when apparent purity or true purity data are required. With this type of material, blending time can be reduced to not less than three minutes without loss of accuracy.

After using this method in all factories the past campaign the author finds the method is to be preferred to the old press juice method and is more reliable. Cost of equipment is definitely not prohibitive and can easily be obtained from suppliers of laboratory equipment.

A Method for Determination of Thin Juice Purity from Individual Mother Beets

ROBERT J. BROWN AND ROBERT F. SERRO[1]

It has long been recognized that there is a good correlation between sugar content and juice purity in sugar beets. Largely because of this parallelism, and the difficulties involved in the determination of purities of juices from individual mother beets as well, the beet breeder has contented himself with selection for quality on the basis of sugar content alone. Another factor in discouraging the use of beet juice purity as a measure of beet quality is the knowledge that the actual criterion of quality is the purity of the defecated beet juice and not the purity of the raw juice.

Because of the desirability of possession of a method capable of giving the purity of thin juice obtainable from individual mother beets, this subject was investigated at our Research Laboratory and the method to be described was developed.

This paper details the procedure and presents comparative results showing the purities of juices obtained by the new rapid method, applicable to volumes of beet juice as small as 50 ml., and the standard lime and carbonation method which requires relatively large volumes of beet juice. Application of this method to experiment station operation, and results obtained in variety test studies, will be presented in another paper by Mr. Ralph Wood, Agronomist, Longmont Experiment Station.

The new method gives the apparent purity of thin juice, agreeing with that obtained by the standard lime defecation and carbonation procedure within the limits of analytical error, is very rapid, requires only a small sample, and is adaptable to mass operations. It involves defecation of the beet juice sample with milk of lime and removal of the lime in two stages with oxalic acid, simulating standard sugar house techniques at first and second carbonations. This procedure may be referred to as oxalation. It has been tested in the laboratory and has demonstrated its ability to produce satisfactory results with proper attention to details of procedure. It fails in the same manner as does standard carbonation procedure. That is, when insufficient lime for defecation of the juice is used, and when pH is not properly controlled at the first and second oxalation steps (equivalent to 1st and 2nd carbonation), an off quality juice may be expected, with accompanying error in juice purity.

Method of Purity Determination

Juice pressed from rasped beet pulp is the starting material. Commonly, plenty of pulp will be available for the test. When individual mother beets are being tested, a special rasp is required, which will provide a quantity of rasped pulp sufficient for the necessary tests. The requirements are generally met by use of a rasp which cuts a 36° sector from the root. This

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will provide approximately 100 grams of pulp from a mother beet weighing 1 kilogram. Thirteen grams of the pulp are used for the sugar and other tests and the remainder is used for the purity test. This residual pulp is placed in a small piece of duck filter cloth and the juice is quickly pressed, using a Carver laboratory press. If 50 ml. of juice are not obtained, the necessary quantity of water is poured onto the press cake, and the pulp is re-pressed. The writers recognize that this simple procedure will not be satisfactory if the mother beets are of small size, and a process for preparation of ca 100 gms. of suitably finely divided pulp, representative of the whole beet root, will need to be devised.

A 50-ml. sample of press juice is treated at room temperature with 1.1 gm. CaO in the form of a 20 percent milk of lime, mixed thoroughly and allowed to stand about five minutes. More lime may be required if green beets are being tested. Great excess of lime is undesirable because of the dilution of the sample later associated with its removal by oxalic acid.

The limed juice is titrated to 11.2 pH with a practically saturated solution of oxalic acid, using a titrimeter standardized at 11.0 pH, with a standard buffer. Juice quality suffers from overrun in this titration, just as in overcarbonation at the first carbonation station. The quantity of oxalic acid required at this step is ca 18 ml. and any large departure from this quantity shows error in lime addition, oxalic acid concentration or pH at the end point of titration.

After the first titration the mixture at 11.2 pH is heated in a steam or hot water bath to 60°-70° C. and filtered on a 9-cm. Buchner funnel, using a small quantity of celite filter aid. The filtration requires 3-5 minutes, giving a pale straw-colored juice. Off color is indicative of improper manipulations or spoiled beets and such samples are discarded.

The first oxalation filtrate is titrated with the oxalic acid solution to 9.2-9.3 pH, using a titrimeter standardized with a standard buffer at this point of the scale. This second titration generally requires 0.8 to 1.4 ml, of oxalic acid. The juice at 9.2-9.3 pH is heated to 60°-70° C. and may be very readily filtered by gravity, using a small amount of a celite filter aid, and filter paper such as Whatman No. 5.

The sparkling pale yellow filtrate is read directly, without lead acetate treatment, in a 400-mm. tube, and the refractometer dry substance of the juice is read as accurately as possible. The Precision Model Refractometer is recommended, or a dipping type, if suitable provision is made for accurate temperature control. Under these conditions, an error of 0.1° V in the polariscope reading is equivalent to an error of somewhat over 0.1 point in purity, but an error of 0.1 in refractometer reading is equivalent to an error of about 1-1.5 percent in purity. The purity is taken from the proper purity tables, or calculated, employing the refractometer solids as brix and taking the corresponding specific gravity of the solution.

Results

Most of the results to be presented give comparisons of purity determinations on thin juices prepared from large batches of press juice by standard carbonation and by the new oxalation method. To date, only a few tests have been made on individual roots.

Table 1 gives the comparison of apparent purities obtained by the two methods on samples of rasped pulp representing five different varieties grown in 1952.

Table 1.—Thin Juice Apparent Purities—1952 Beets. Thin Juices Prepared by Carbonation and Oxalation.

Variety No.	Apparent Purity Thin Juice	
	Standard Carbonation	Oxalation
1	88.8	88.1
2	90.7	90.2
3	90.0	90.4
4	92.5	92.2
5	90.1	90.1

In this set of results the sugar content of the carbonated thin juice was determined by polarization of 52.0 gms. of thin juice made to 100 ml.

The beet pulp representing Variety No. 4 was preserved in the deep freeze for about six weeks and then rerun by the oxalation method. The purity shown in the second test was 92.3, showing no change on long storage of the pulp.

Table 2 lists comparative results, obtained by the two methods of preparation, on press juices from beets of the 1953 season.

Table 2.—Thin Juice Apparent Purities—1953 Beets.

Description of Beets	Apparent Purity Thin Juice	
	Standard Carbonation	Oxalation
Commercial—Brighton	90.8	91.5
Commercial—Longmont	93.1	93.7
Experiment Station—		
Variety No. 1	87.7	88.1
Variety No. 2	90.5	90.9
Variety No. 3	90.1	90.0
Variety No. 4	91.8	91.4
Variety No. 5	90.6	91.8
Variety No. 6	91.0	91.9

The results on 1953 beets suggest a tendency toward higher purity of the juice prepared by oxalation, especially noted in varieties 5 and 6. Previous experience with laboratory carbonation operations on press juice had demonstrated a tendency toward variable results when only 2 percent CaO on beets is used at carbonation. Therefore, three of the above samples were treated with both 2 percent and 3 percent CaO in both methods of thin juice preparation. The results are given in Table 3.

Table 3—Thin Juice Apparent Purities Using 2 and 3 Percent CaO on Beets.

Description of Beets	% CaO on Beets	Apparent Purity Thin Juice	
		Standard Carb.	Oxalation
Experiment Station—			
Variety No. 4	2.0	91.8	91.4
Variety No. 4	3.0	92.1	92.0
Variety No. 5	2.0	90.6	91.8
Variety No. 5	3.0	92.4	92.2
Variety No. 6	2.0	91.0	91.9
Variety No. 6	3.0	91.5	91.9

Increasing the amount of lime used increased the purity of the juice prepared by oxalation an average of 0.3 points, while that of the carbonated juice was increased by 0.9 points. The point to be noted is not that more lime should be used in the oxalation procedure, but unless sufficient lime is used in the carbonation procedure to insure complete defecation, a low purity of juice may be found. Apparent purities of carbonated juices listed in Tables 2 and 3, were run by the method used for measuring the purity of oxalated juice.

Table 4 shows the purities of juice obtained from individual beets of the 1952 season and stored in the root cellar about four months before test.

Table 4.—Apparent Purities of Thin Juice from Individual Beets.

Root Description	% Sugar	Thin Juice Purity
Billings No. 1	16.7	90.6[1]
Billings No. 2	18.7	95.1
Billings No. 3	18.6	94.1
Billings No. 4	15.8	94.4
Gering—Variety A		
Gering No. 1		91.8
Gering No. 2		91.0
Gering No. 3		88.8[1]
Gering—Variety B		
Gering No. 1		93.5
Gering No. 2		91.8
Gering No. 3		87.9[1]
Sterling No. 1	15.3	94.9
Sterling No. 2	15.0	93.3
Sterling No. 3	15.1	94.6

[1] Off color thin juice showed deterioration of roots during storage.

Discussion

Probably the principal question concerning the acceptability of the new method will arise from a question as to how closely the purity of defecated press juice is related to the purity of defecated diffusion juice obtained from those beets in factory operations.

A number of years ago our Research Laboratory had occasion to investigate effects of varying the conditions of digestion of cossettes on the purity of thin juice obtained from the extract, as compared to the purity of standard carbonated press juice. The effects of varying the quantity of water used (ranging from 50 percent to 100 percent on cossettes), the temperature of digestion (ranging from 60° C. to 90° C.), the time of digestion (ranging from 1 hour to 2 hours), and the final pH of the extract (ranging from 6.5 to 5.5), were surprisingly small except when 2-hour digestion at 90° C. was used. The average apparent purity of carbonated press juice from cossettes used in 21 tests was 92.5. The average purity of carbonated diffusion juices obtained under the varying conditions of the 21 tests was 92.2. It can hardly be questioned that the purity of carbonated press juice obtained from beets shows the purity of the thin juice which the factory may be expected to obtain from those beets.

The data in Tables 1, 2 and 3, demonstrate that the oxalation technique provides a quick, accurate method for determination of thin juice purity.

The few results given in Table 4 show significant purity variations in beets of a single variety, and they also indicate that the sugar content of the beet, and the purity of thin juice obtainable from it, are not necessarily parallel. Selection of roots for thin juice purity is feasible and apparently has much to offer to the industry.

When it is desired to select beets for low content of raffinose and other constituents, such as amino acids and non-sugar carbohydrates, the thin juice provides an excellent sample for this purpose. No preparation other than dilution to a standard concentration is required for tests by paper chromatography.

Summary

A rapid method for obtaining the purity of defecated thin juice from the small quantity of press juice available from individual mother beets is detailed.

Data are presented to show that the purities obtained by the new method called oxalation, and by standard carbonation, are essentially identical.

A few results are given to demonstrate the desirability of employment of thin juice purity, as well as other factors, in selection of mother beets.

Further Experiences with Algins

H. E. HALDEN[1] AND SOMERS MOORE[2]

Introduction

A paper, "Chemical Aids to Carbonation Mud Settling and Filtration," by Somers Moore (1)[3], was presented at the seventh general meeting of this Society.

The paper dealt chiefly with the use of sodium alginate, commercially known as Kelgum and manufactured by the Kelco Company, as a settling aid for first carbonation juices. It was found that the addition of Kelgum solution to first carbonation was beneficial, with maximum results under certain specific conditions:

a. When added as a 0.1 percent solution in water.

b. When quantity added is near 2 ppm in juice.

c. When the condition it is designed to remedy is not the result of irregularities at the carbonation station.

Two generalizations about the use of algin as a settling aid were made:

a. Algin almost always helps the settling of the thin juice slurry, but as the susceptibility of the juice decreases, trouble develops with the thicker slurry.

b. Juices which are naturally the best settling are the most susceptible to the action of algin.

Recent work has verified these observations and has increased our knowledge of the action of Kelgum. The present paper will only deal with findings which have not been covered previously.

Factory Experiences

During the 1953 campaign two algin preparations, manufactured by the Kelco Company: Kelgum (78 percent algin) and Kelgin (90 percent algin) were used by the Spreckels factories as settling aids for first carbonation juices. In laboratory tests the efficiencies of the two have been found to be practically equal when based on equal algin content. In actual factory use on difficult settling juices Kelgin may be slightly more efficient than Kelgum.

At two of the factories, one Steffen and one straight house, where Kelgum had been used during the three previous campaigns, the Kelgum solution was added to the whole first carbonation juice entering the Dorr thickener. At the third, a Steffen house, where the use of algin had been found to be ineffective in previous campaigns, both in actual use in the factory and by laboratory settling tests (described later), the first carbonation alkalinities were lowered during the 1953 campaign from the previous normal value of around .080 to the vicinity of .065—.070, to increase factory capacity by improving the rate of settling in the thickener. In this lower alkalinity region, laboratory tests indicated that improvements in settling

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[3] Numbers in parentheses refer to literature cited.

could be expected through the use of algin. These tests also showed that slightly better results could be obtained from Kelgin rather than Kelgum.

At first the Kelgin solution was added to the juice feed prior to entering the Dorr thickener. An improvement was noted. Later, and for the remaining portion of the campaign, the Kelgin solution was added in such a way that the conditioning compartment of the thickener, in this case including about one-third the volume of the thickener, was bypassed. This method of addition was adopted under the assumption that the Kelgin was losing its effect with time of contact with the juice. A much more pronounced favorable effect resulted, both on settling and sludge filtration rates, when the Kelgin was added in this manner. Whether this bypassing of the conditioning compartment would have enabled the Kelgin to show a beneficial effect when operating first carbonation at the normal alkalinity of approximately .080 has not been determined.

General Considerations

The effects of Kelgin addition to the juices of this factory were determined in a laboratory settling test apparatus (2), in which such data were obtained as: the thickener area required to clarify a given material for a given amount of solids and a fixed underflow discharge ratio; and comparisons of settling characteristics of different materials. The capacity of a thickener is dependent on the slowest settling curve, depending upon physical and chemical circumstances. The curves obtained by plotting the sludge concentration against the values of C (pounds solids which can be settled per square foot of thickener area per hour) have been classified into three types: the A curve, in which the settling rates of sludge as thin as or thinner than feed materials determine the thickener capacity; the C curve in which settling of the nearly completely thickened material determines the capacity, and the B, or transition type, curve.

In most cases the A curve is obtained at lower alkalinities in the region .065—.070, with transition curves in between .070 and .080, and marked C curves first appearing from there up to .090. There are many exceptions. The alkalinity point of change from A to B curve varies with the types of nonsugars, depending on the beets, and is lowered by increase in the amount of lime used and by decrease in the Brix of the raw juice. In general an A curve is associated with a higher overall settling capacity, but also a poorer thin juice quality. A C curve is associated with higher quality thin juices. If a turbid overflow is experienced with a C curve, and sufficient filtration capacity is at hand, relief may be experienced by drawing off more underflow.

In the case of the particular Steffen factory referred to above, since filtration was a bottleneck, the type A curve was obviously most desirable.

Results of Laboratory Tests

Figure 1 illustrates the effect of 2.5 ppm. Kelgin on a juice of .087 alkalinity as compared to that on the same juice at .067 alkalinity. At the higher alkalinity the top settling rates are only slightly improved by the addition of Kelgin, and the bottom rates are slightly retarded. The curves

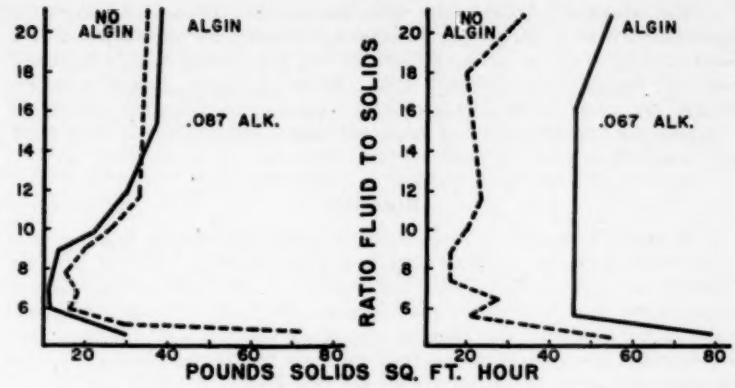

Figure 1.—Relative Efficiency of Algin (2.5 ppm.) at different alkalinities.

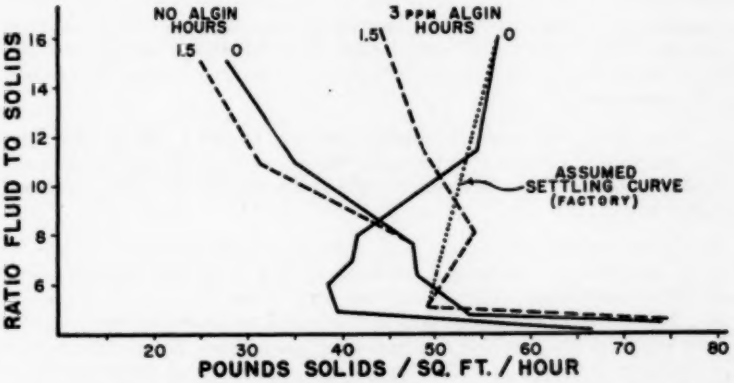

Figure 2.—The effect of time on settling of first carbonation juices with and without algin, .067 alkalinity.

in both cases are definitely of type C. At .067 alkalinity there is a very decided improvement, roughly two times, in the settling rates from the use of algin. In both cases lowering the alkalinity has produced a curvve of the B type.

Figure 2 illustrates the effect of time on the settling curves, with and without the use of Kelgin. The juices for the delayed tests were kept in a water bath for 1.5 hours at 80° C. The alkalinity was .065.

The effect of time on the settling rates of untreated first carbonation juice is slight. With 3 ppm. of Kelgin, the settling curves obtained from this particular juice permit some significant deductions.

The laboratory settling tests show that on the addition of Kelgin the immediate effect is that the curve appears to pivot around a point at a fluid to solids ratio of about 10, so that the top settling rate is increased and the bottom rate is slowed down. After 1.5 hours' contact with the Kelgin, the curve pivots back around the same point, reverting toward the curve of the original untreated juice, but with an increase of overall thickener capacity.

Discussion

In the laboratory tests, each series of determinations on different concentrations of sludge is made within a relatively short interval of time, and the curves shown on Figure 2 are of more or less "instantaneous" nature. In a factory thickener with a total detention time of 1.5 hours, the actual time of contact with the algin is very short for the top concentrations. Considering this, the actual settling curve in the factory would probably be somewhat of the nature of the dotted line shown.

It is clear that algin improves the settling rates of the less concentrated mixtures of sludge and juice, and that it retards the settling rates of the more concentrated mixtures. It is likewise apparent that the effect of algin decreases with time. It is thus somewhat fortuitous that when inserted into Dorr feed material its initial effect is an advantageous one, and the effect on the thickened mixtures, which is reduced due to time of contact, is an undesired one.

Thus, from this work, it appears that the proper place to add algin is at the commencement of thickening, bypassing the conditioning compartment, and that it is not desirable to add it directly to the nearly thickened materials.

Factory experiences at the two other Spreckels factories continue to verify the efficiency of Kelgum addition to first carbonation juices under controlled conditions. The reason that algin works well at alkalinities of near .080 at two factories, and only at lower alkalinities at the third, appears to be related to the fact that A curves are obtained only at lower alkalinities in the third factory, and it has been shown that A curves are essential for algin to be useful. Why this difference in the alkalinity-curve type relation exists at the third factory is not determined, but may be involved in carbonation equipment characteristics, or in the presence of reburned lime in the liming reagent.

Conclusions

Since the paper given at the seventh general meeting, it has been found that:

1. Algin when added to first carbonation juices in amounts of about 2-3 ppm. has an accelerating effect on sludge settling rates in the more dilute mixtures of sludge and juice, and a retarding effect in the more concentrated mixtures.

2. The effectiveness of algin decreases very slowly with time of contact with the juices.

3. In practical usage, the result of points 1 and 2 is fortuitously advantageous, since the algin reaches the nearly thickened mixtures after the longest detention time.

4. Algin may be used to advantage with sludges and under conditions giving type A settling curves. Since type A curves are obtained under somewhat different conditions at different factories, due probably to differences in reagent materials, this possibly explains why algin appears to be of value at some factories and not at others.

5. For maximum beneficial effect, algin should be introduced into the thickener feed, shortly before it enters the settling compartments, and never to nearly thickened materials.

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An Experimental Micro Filter

WALTER O. BERNHARDT[1]

In the study of the filtration characteristics of factory slurries and experimental materials the need for a miniature filter is often felt. Such a filter should be capable of operating on a small volume of material, yet furnish precise and reproducible data. Olof Wiklund and Lars Lindblad (1)[2] describe the use of such a filter—the Dedek Micro Filter—for the study of carbonation slurries (Figure 1).

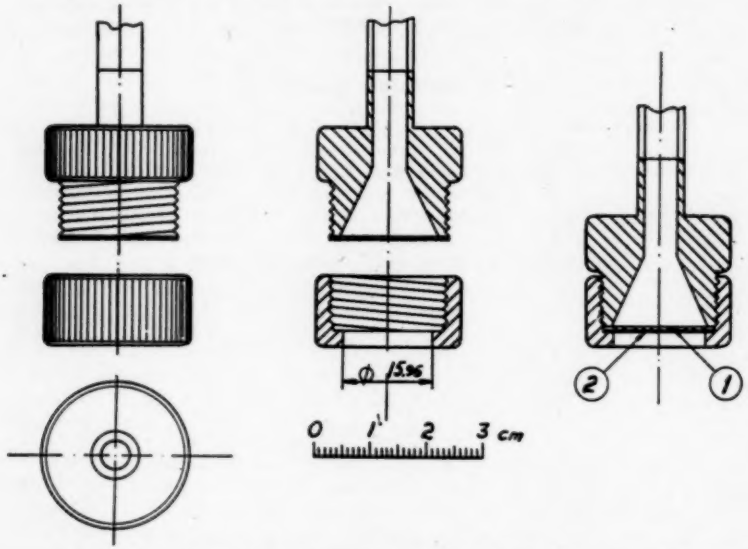

Figure 1.—Dedek Micro Filter (Filter Area 2cm.²). 1 = wire grid, 2 = filter paper. From: Olof Wiklund and Lars Lindblad, Socker 5, 162-63 (1949) by permission.

It consists essentially of a measuring pipette with a septum holder attached. The septum holder accepts a sheet of filter paper with an effective area of 2cm². The pipette is graduated in units of 2 ml. In use the septum holder is immersed in the beaker containing the slurry, which is being agitated by a small stirrer, and the pipete connected to a source of vacuum. From the times (in seconds) required to pass the first, second and third graduation marks on the pipette a filtration coefficient, Fk, is calculated by the Brieghel-Mueller method (2).

During an investigation of filtration characteristics of slurries from low-lime defecation this filter was found to be unsuitable. The agitation of

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[1] Research Engineer, Spreckels Sugar Company, Woodland, California.
[2] Numbers in parentheses refer to literature cited.

the slurry—necessary for the maintenance of a constant mixture—provided sufficient attrition on the surface of the cake to impair the value of the data. A further disadvantage, especially when working with very low filtration pressures, is the progressive reduction in effective pressure due to the column of filtrate accumulating above the septum.

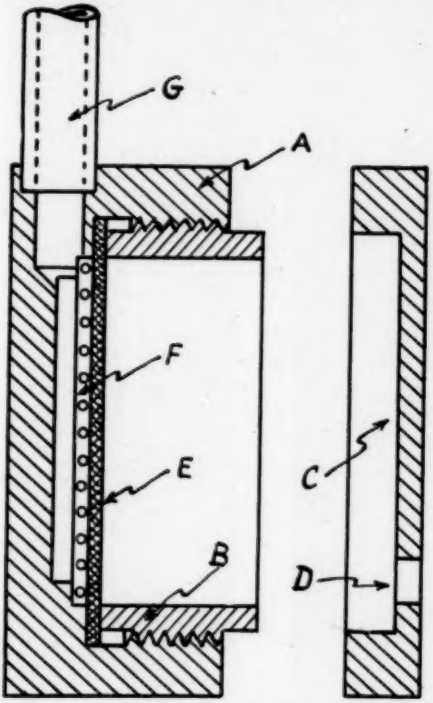

Figure 2.—Improved Micro Filter

A—filter housing

B—septum retainer

C—cover

D—slurry inlet

E—filter septum

F—supporting screen

G—filtrate outlet

A new filtration appartatus (Figures 2 and 3) was designed to overcome these shortcomings of the Dedek filter. To prevent attrition due to agitation the septum is enclosed in a filter chamber and a small opening provided in the cover for entrance of the slurry from the beaker, where it is subjected to the required agitation. The filtrate leaves the septum holder at the top, thus displacing all air in the holder; it enters the measuring pipette above the maximum filtrate level and thus insures a constant filtration pressure. A water bath around the beaker provides for a constant temperature. Agitation is supplied by a crescent-shaped paddle which oscillates slowly in a vertical direction. The paddle is driven by a geared motor through a connecting rod and horizontal beam. Speed and stroke are adjustable to meet the requirements of different slurries. The effective filter area—2.46 cm^2—was selected to facilitate the conversion of data; a filtrate volume of 10 ml. through the micro filter is equivalent to 1 gallon through a filter area of 1 ft^2.

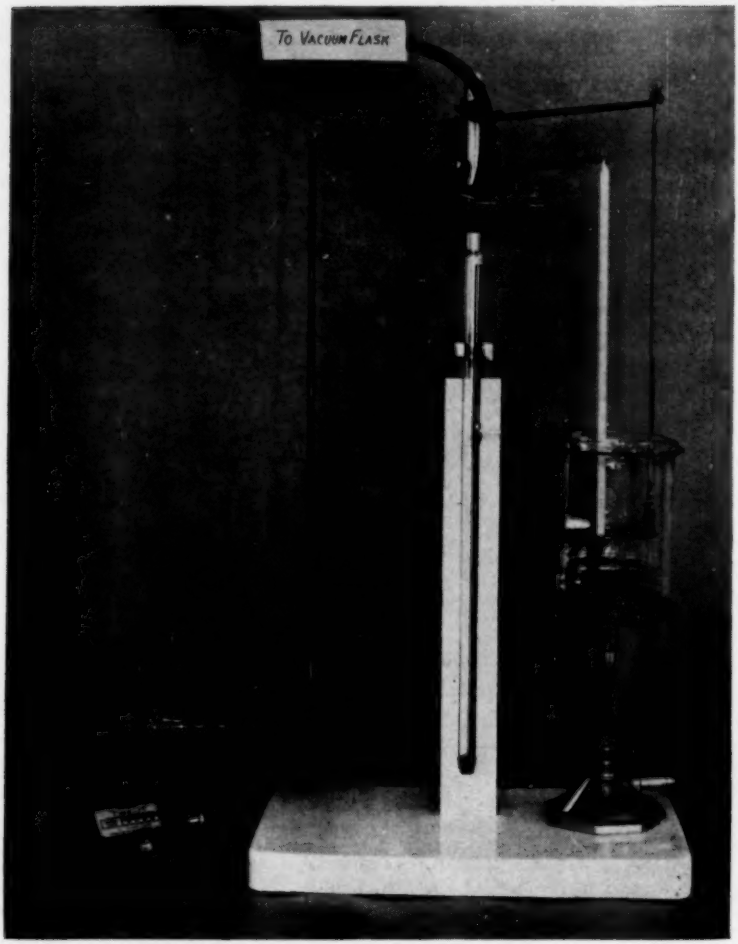

Figure 3.—Microfiltration Apparatus.

The Brieghel-Mueller calculation of Fk was abandoned. While the constant, Fk, permits a comparison of the relative filterability of slurries, it does not readily lend itself to the calculation of the capacity of factory filters. After a search of the literature the method of B. F. Ruth, G. H. Montillon and R. E. Montonna (3) was adopted as most suitable. In combination with the micro filter, using reasonable care, this method yields filtration constants with an accuracy exceeding the requirements for precise engineering calculations. The entire filtration cycle follows the equation $(V + C)^2 = K(\Theta + \Theta_o)$, wherein V is the filtrate volume passed in the

time Θ, K is the filtration constant and C and Θ_0 are related to septum resistance. B. F. Ruth shows that this simple equation holds true for all types of slurries, regardless of rigidity or compressibility of the filter cake. Since many of the materials encountered in the sugar industry exhibit compressibility of varying degrees, the advantage of the Ruth equation is obvious.

To perform a filtration the apparatus is assembled as shown in the photograph (Figure 3). With the pinch clamp at the top of the pipette closed, a five-gallon flask is evacuated to the desired filtration pressure—indicated on a mercury manometer. With the agitator in operation and the filter chamber in place and connected to the pipette, the temperature of the slurry is adjusted by manipulation of the burner below the water bath. A thermostated water bath is of advantage when a large number of filtrations must be performed. An electric stopwatch is used to measure elapsed time. Depending on filtration rates, times at 1, 2 or 4 ml. intervals are recorded. The count of time starts with the application of vacuum to the filter by opening of the pinch clamp. Table 1 shows a set of data from a slow filtering slurry of high compressibility, with a sample calculation. Observed and calculated values are tabulated side by side.

Since the data of a filter test, according to Ruth, comprise a portion of a perfect parabola it is permissible to calculate the values for C and K from only three points on the curve with a fair degree of accuracy. This was done in the sample calculation and the validity of this statement is indicated by the close check of observed and calculated values for Θ and V.

Table 1.

V(ml.)	Θ(sec.)		Θ(sec.)	V(ml.)	
Obs.	Obs.	Calc.	Obs.	Obs.	Calc.
2	35	36	35	2	1.95
4	100	98	100	4	4.05
6	190	190	190	6	6.01
8	310	311	310	8	8.00
10	460	461	460	10	10.00
12	642	641	642	12	12.03
14	856	850	856	14	14.07
16	1090	1088	1090	16	16.03
18	1356	1356	1356	18	18.02

Sample Calculation

Θ	$\Delta\Theta$	V	ΔV	V+ΔV/2	$\Delta\Theta/\Delta$V
35		2			
	425		8	6	53.13
460		10			
	896		8	14	112.00
1356		18			
			Difference:	8	58.87

Slope = 58.87/8 = 7.358

K = 2/7.358 = 0.272

C = (53.13/7.358)—6 = 1.22 ml.

Θ_0 may be calculated by substituting several early values of V in the equation $(V+C)^2 = K(\Theta+\Theta_0)$, and averaging the results. Thus Θ_0 = 1.7 sec.

The small deviations in the example are doubtless due to the difficulty of reading elapsed time on the stopwatch at the precise moment when the liquid level in the pipette passes the graduation.

During a study of the effects of controlled variables on filtration rates of factory and experimental slurries, several hundred filtrations were performed with this micro filter for the determination of constants. While a more elaborate timing apparatus may appear desirable, the data from the present equipment were found sufficiently reliable.

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Theory and Economics of Diffusion

HUGH ROUNDS[1] AND FRANK N. RAWLINGS[2]

First of all, what are the objectives of diffusion?

1. As completely as possible transfer the sugar from the cossette of the beet to the solution phase or diffusion juice.

2. Leave in the diffused pulp the maximum of nonsugars. This selective extraction of sugar in diffusion constitutes one of the two purification steps in current processing methods generally employed in the beet sugar industry, the other being defecation.

3. Accomplish the above two objectives with a minimum of dilution of the sugar.

The objective in process control is to find the equipment and process conditions which accomplish the most profitable compromise of these objectives. To evaluate where we stand today on this diffusion job, we need to know what is being accomplished with respect to each of the above enumerated objectives and at what cost.

To illustrate what is being accomplished with respect to completeness of transfer of sugar in the cossettes to the solution phase or diffusion juice, the three chain diffusers at the Nyssa, Nampa, and Twin Falls plants of The Amalgamated Sugar Company were calculated for the 1953-54 campaign to date of writing. They show the values illustrated in Table 1. This calculation assumes no unknown loss in the diffuser.

To illustrate what is being accomplished with respect to diffusion elimination on the same three diffusers refer to Table 2.

Table 1.

Factory	Percent Non-sugar Elimination in Diffusion
Nampa	21.9%[1]
Twin Falls	20.9%[2]
Nyssa	16.2%[2]

[1] Cossette purity by spindle method, diffusion juice by refractometer, cossette purity by Waring blendor method.
[2] Both cossette and diffusion juice purity based on refractometer brix. Cossette purity by Waring blender method.

Table 2.

Factory	% Input Sugar in Outgoing Diffusion Juice	Draft by Sugar Content	Daily Slicing Performance Tons/24 Hour
Nampa	99.03	128	3443
Twin Falls[1]	99.09	135	3295
Nyssa	98.78	133	3842

[1] 19-Cell Diffuser.

[1] Supervisor, Central Laboratory, The Amalgamated Sugar Co., Twin Falls, Idaho.
[2] Director of Research, The Amalgamated Sugar Co., Ogden, Utah.

Looking at diffusion from the standpoint of the amount of dilution suffered to accomplish the above listed results, we use Nampa as the example. In the beets processed at Nampa, there existed 4.94 pounds of water per pound of sugar content. In the diffusion juice realized the water content per pound of sugar had been increased to 7.16 pounds. In other words, a dilution of 2.22 pounds of water per pound of sugar was sacrificed to bring about this 99 percent translocation of sugar to the liquid phase. If there existed an expulsion method in which the marc of the beet could be squeezed absolutely dry and free of sugar, the juice would have 2.22 pounds of water less per pound of sugar content.

Admittedly these next figures are an over-simplification, but they illustrate the cost of this diffusion dilution and portray the economic benefits which would result from the perfect sugar separation—if it could be found—in relation to the present continuous diffusers. Using a figure of 2.1 pounds of water evaporated per pound of steam and a "to burner" fuel cost of 41c/1,000,000 BTU and a boiler efficiency of 85 percent, the material cost of evaporating this extra 2.22 pounds of water per pound of sugar, which results from diffusion dilution, is .051c. On top of this would come the capital, maintenance, and overhead costs of this additional steam producing and evaporating equipment—which might be expected to raise the cost of evaporating this additional 2.22 pounds of water per pound of sugar to 0.075c or 7.5c per 100 pounds of sugar in cossettes.

This then would represent the possible magnitude of saving of the perfect diffuser, provided—

1. it could be installed and operated as cheaply as present diffusers,
2. it would realize as great a non-sugar elimination as that accomplished by present diffusers, and
3. it would leave the by-products equally recoverable. These last two provisions provide a stiff challenge to any new improved sugar extraction method.

A clear-cut concept of the cost of current operating methods is usually most valuable in directing efforts towards most profitable avenues of improvement in any processing problem. Following this reasoning let's look at current costs of diffusion first, and then look at some values of non-sugar elimination to see which avenue appears most valuable in improving diffusion, and also how much sacrifice of one might be justified to gain on the other.

First, look at some operating costs on the present Silvers diffusers. It is necessary to make some assumptions to set up these costs, so the following costs in Table 3 will be used.

If the assumptions of Table 3 are valid, then for current conditions it is evident that if either the capital cost or operating cost of the total diffusion bill could be reduced say 25 percent, the saving would be of the order of 2c per bag of sugar.

Turning attention now to the values of non-sugar elimination related to processing costs, it was stipulated at the beginning of this presentation that any evaluation of new sugar extraction processes for beets should include careful comparison of the ability of the competitive process to give non-sugar eliminations equal to present diffusers and leave the by-products—pulp—equally recoverable.

Table 3.—Estimated Cost of Beet Diffusion, Silver Chain Diffuser.

Assume	
Tons beets sliced per year =	300,000
Tons sliced per day =	3,250
Capital Cost	
12-foot—Scroll & Wheel Diffuser	$300,000
Building for Diffuser	75,000
Annual Amortization	
Diffuser (25-year schedule)	12,000
Diffuser Building (40-year schedule)	1,875
Annual Maintenance Cost	
Diffuser	18,500
Diffuser Building	2,500
Labor (Including Knife Station)	
With company contributing payments	15,407
Steam	
Only that lost in radiation and heat in pulp. (Heat in juice considered part of evaporation.) Cost at 48c/1,000,000 BTU	12,900
Supplies	
Knives, routers, etc.	6,000
Total Diffusion Cost per Year =	$ 69,182
Total Diffusion Cost/Ton Beets =	23.1c
At 280 pounds sugar sacked/ton beets	
Total Diffusion Cost per Bag of Sugar =	8.2c

Table 4.—Nampa Non-Sugar Elimination—1952 Campaign.

	Percent Elimination
Total Non-Sugars (Double Enzyme T.P.)	21.05%
Raffinose	None
Invert Sugar	57.75%
Ash	7.71%
Amine Compounds	33.16%

What does this mean? The three factories used herein as examples had diffuser non-sugar eliminations for the current campaign to date of writing ranging from 16.2 percent to 21.9 percent. For a more detailed analysis of the non-sugars eliminated through diffusion refer to Table 4. These represent carefully composited samples taken and immediately frozen twice each shift for the duration of the 1952 campaign at the Nampa, Idaho, factory and analyzed on a weekly basis.

Some of the disappearance of invert sugar is undoubtedly through bacterial assimilation which imparts other bacterial end products as a partial replacement.

The non sugars enumerated in Table 4 are not currently removable to any large extent through carbonation. Therefore, if they are not eliminated in diffusion, they proceed through the process to form molasses.

Any sugar separation process—such as steam explosion—which is evaluated against conventional diffusion must be carefully examined with respect to non-sugar elimination. For example, two-thirds of a pound more of non-sugars left in deficated juice extracted from a ton of beets will result in the loss of roughly a pound of sugar in molasses. At today's nets for sugar and molasses, this loss of value approaches one-quarter of the total cost of diffusion enumerated in Table 3. Look at it another way: For factories of

the 3500 ton class each one one-hundredth of one percent of additional non-sugars percent on beets going through to the sugar end, represents a loss of revenue of $50-$65 per day, depending on the sugar net and molasses price that fits your area. This is a half-cent or better per bag of sugar for each one-hundredth of a percent non-sugars percent on beets.

These thoughts lead to the question of whether the possibilities of improvement of diffusers or diffusion have been exhausted. Our feeling is that we cannot answer this question with any assurance since the industry knows very little factually of the effects of the different variables of diffusion.

Our search for reliable information on diffusion led us to the conclusion that about all that is known of diffusion mechanics is the result of observations of commercial practice. Since the raw material is variable from hour to hour and day to day, reliable comparative data is almost impossible to obtain in plant operation. To the contrary, many witches' tales have grown up among operating personnel because at some time they may have tried some adjustment which actually had an adverse effect, but due to a simultaneous change of beets, a contrary conclusion was drawn. Some of these persist for years. It is difficult to combat them since no reliable information exists with which to counter.

Another factor contributing to the slow development of knowledge with respect to diffusion is the yard stick of evaluation. The yard stick of evaluation is purity, and due to the fact that this measures sucrose and sucrose is highly predominant—large and significant changes of non-sugars do not show up dramatically and tend to be overlooked.

Take a specific example of a factory which—during the first week of campaign—had a diffusion juice true purity of 88.29, and on the sixteenth week had a true purity of 85.53. The purity was 2.76 points higher at the beginning of campaign on fresh beets. We know that's appreciable, but does it strike you as forcefully as when you see that the non-sugars per 100 pounds of sugar increased from 13.26 to 16.92, an increase in non-sugars of 27.6 percent. Another way of looking at this is that the non-sugars were increased by 3.66 pounds/100 pounds of sugar. If carbonation removes 25 percent of these, there still exists an increase of 2.75 pounds of non-sugars going to molasses, which will carry with them into molasses approximately 4.13 pounds of sugar.

With this as background, it was felt that the only way we could learn more about diffusion was to build a small controllable diffuser, so that a given set of cossettes can be split into several fractions. Then changing one variable on these successive portions of cossettes, the specific effect of the change of this variable can be determined without introducing error from a change of beets or a change of other process variables. Central Laboratory has been working on this problem for two campaigns now. They have successfully developed a continuous diffuser, which is controllable and which duplicates very closely the results under given conditions obtained with these same conditions in a factory diffuser.

A substantially greater problem has been that of developing analytical procedures sensitive enough to reflect the small changes of various classes of non-sugars.

Basing conclusions on work with synthetic solutions and also on reproducibility of results on factory products, it has been concluded that for total non-sugar grouping the sucrose purity by the double enzyme method is most accurate. In our district, it appears that the other polarimetric materials than sucrose present are close enough to compensating to make apparent purity a satisfactory tool for most screening work. It was further concluded that the raffinose results—by the double enzyme method at the level which raffinose exists in diffusion products—are not sufficiently accurate to be usable.

In the work so far, rather than attempt to quantitatively measure the individual constituents of the beet, classes of non-sugars are grouped to measure the diffusion behavior of these groups.

The grouping used currently for evaluation and the method employed are as follows:

Invert Sugar	TASCO modification of the Layne-Enyon Method
Ash	The sulfated, uncorrected method
Amine Compounds	TASCO modification of the Gunning Method
Percent Coagulables	Figures are determined at about 2 and at 11 pH. The product in question is adjusted to maximum flocculation with either hydrochloric acid or calcium hydroxide. The product is then centrifuged in a graduated vial in which the volumetric percentage of coagulables thrown down can be read directly. These are taken as a representation of the quantity of coagulables to be removed by carbonation.

In undertaking a problem such as this diffusion problem where no variable optimums can be assumed to be known and where the number of effective variables is so numerous, a large amount of repetitious work is involved. First, assumed conditions must be adopted for all but one variable. After the optimum is found for that variable under those conditions a second variable is approached. When the second variable optimum is fixed, it is often necessary to go back and recheck the first variable to determine whether the optimum on variable 1 holds under the optimum for variable 2. Due to this complexity and the large number of variables involved, the pilot diffuser work is far from completed.

It has been encouraging, however, that an apparatus and methods have been developed which demonstrate consistently reproducible patterns of results and in which the variables can be controlled within reasonable tolerances.

The diffuser and its operation will not be described in great detail here. The apparatus is a true counter-current diffuser with perforated flights, drawing the cossettes counter through the diffusion tube to the flow of diffusion liquor. The diffusion tube is 3 inches inside diameter with an effective length of 126 inches. The initial 15 percent of diffusion length is provided with separate heating control so that the region can be heated

differentially from the rest of the diffuser. The final 85 percent of diffusion length is in a controllable temperature bath, readily controlled in any range up to boiling temperatures. In the 85 percent of final diffusion travel, variable speed oscilation of the diffuser tube is provided to develop variable mechanical agitation. Provision is made for such factors as control of temperature and flow rate of battery supply, prescalding of cossettes, etc. Variable speed of the diffuser chain is provided. A weighed amount of cossettes is placed in each diffuser flight section so that uniform cossette loading is maintained.

The results herein enumerated are only exemplary of the type obtained demonstrating some of the findings to date.

Table 5.—Diffusion Temperature Constant Throughout.

Diffusion Conditions: Beets—fresh, 15.8% Sugar; Draft—135; Retention Time—36 Minutes	Averages of 3 Sets of Tests				
	65° C.	70° C.	75° C.	80° C.	85° C.
Diffusion Juice Brix	12.04	12.45	12.37	12.38	12.63
Pulp, % Sugar	0.45	0.40	0.29	0.29	0.33
% Non-Sugar Elimination	17.1	19.9	18.1	15.9	8.2
% Ash Elimination	15.7	17.4	17.5	17.1	18.1
% Amine-Compound Elimination	34.5	34.4	33.9	37.7	39.6
% Invert Elimination	34.4	39.8	48.4	48.4	36.6

Referring to Table 5, these data as shown are the average of three sets of tests. In other words, the results were replicated three times and averaged. It should be pointed out that for a series of tests the beets to be used are washed and axially segmented lengthwise of the beet, with one segment being thrown in each pile up to the number of tests planned. Each pile has an equal wedge segment of each beet to eliminate any chance of variability of raw material. The samples are immediately placed in vapor tight plastic bags in a refrigerator until test time when they are totally cut to cossettes, mixed, and diffused. The samples evaluated are taken after the diffuser has reached equilibrium. Recent tests on marc value indicate that some drying of pulp is taking place in the draining section of the diffuser so the exhaustion is greater than shown. No correction for this drying was made in the tests reported herein. In this series the temperature was raised in the first 15 percent of diffusion travel to the given value and maintained constant at this level throughout the remainder of diffusion. In other words, this is as nearly as possible a constant temperature diffusion. The maximum over-all non-sugar elimination of this series manifests itself at a diffusion temperature of 70° C. with maximum exhaustion being manifest at 75-80° C. It is worth noting that the ash elimination is not significantly sensitive to temperature. The elimination of amine constituents is significantly higher at temperatures of 80° C. and above. It is also interesting to note that the amine constituents are the class of non-sugars eliminated to the highest degree. Factory tests have borne this out.

The apparent invert eliminations shown herein are very high, but show no pattern of trend with temperature. It should be pointed out that dif-

fusion juice from the experimental diffuser shows no lactic formation, so that bacterial fermentation cannot be credited with the invert disappearance. Thermal alteration of invert, however, is a probable factor in the high apparent invert elimination.

For a time in the earlier diffusion studies raffinose was followed with erratic results, which were traced back to the weakness of the analytical method. No appreciable raffinose elimination was observed, and this has been confirmed on factory samplings.

A continuing effort has been made to evaluate the acid and alkali coagulatable factors in the diffusion juice to measure their pattern of elimination. Only recently has what is now considered a satisfactory method been developed. So far, they demonstrate no appreciable elimination of acid coagulatable factors and the alkali cogulatables have shown from "no elimination" to a "small, negative elimination."

Table 6.—Diffusion Temperature Varying in First 15% of Cossette Travel, Remaining Portion of Diffuser at 70° C.

Diffusion Conditions:
Beets—fresh, 16.4% Sugar
Draft—135
Retention Time—36 Minutes

	Averages of 3 Sets of Tests			
	Entire Diffuser	First 15% of Cossette Travel		
	70° C.	80° C.	85° C.	90° C.
Diffusion Juice Brix	12.30	13.25	12.85	13.63
Pulp, % Sugar	0.46	0.43	0.40	0.29
% Non-Sugar Elimination	17.9	23.7	24.4	21.0
% Ash Elimination	9.1	13.5	12.7	11.9
% Amine-Compound Elimination	30.5	32.3	33.5	31.6
% Invert Elimination	32.9	48.8	43.9	40.2

Referring now to Table 6, this series was set up to test the merit of holding the head end of the diffuser at a higher temperature than the rest of the diffuser. This is the conventional method of operating, but the question was how much higher temperature, if any, on the head end would derive the optimum result. Since the series in Table 5 demonstrated optimum uniform temperature diffusion at 70° C., this series reported in Table 6 was set up to heat in the first 15 percent of travel to temperatures of 80, 85, and 90° C., with the remainder of diffusion travel held at 70° C. in all cases. A duplication of the 70° C. uniform diffusion was also placed in this series for direct comparison. It's worth mentioning here that Table 5 anticipates that higher temperature on the head end might give improved elimination by virtue of raising amine elimination due to the short high-temperature exposure, without keeping this high temperature long enough to reap all its detrimental effects.

The results in Table 6 bear out these hopes. They show in all cases an improved non-sugar elimination over the constant temperature diffusion, the optimum occurring with a head end heating temperature of 85° C. This series was conducted with freshly dug beets, as shown.

The increased amine elimination with increased head end temperature is demonstrated. The sugar-in-pulp reduction associated with the higher head end temperatures should not be overlooked.

Table 7.—Pre-Scalding Cossettes to 85° C. with Steam and Diffusing at Various Temperatures.

Diffusion Conditions:
Beets—fresh, 16.3% Sugar
Draft—135
Retention Time—36 Minutes

	Averages of 3 Sets of Tests			
	No Pre-Scald.	Pre-Scalding Cossettes to 85° C.		
	Coss. End[1] 80° C. Rem. 70° C.	Entire Diff. 70° C.	Coss. End[1] 85° C. Rem. 70° C.	Coss. End[1] 80° C. Rem. 70° C.
		*	*	*
Diffusion Juice Brix	13.14	10.72	11.93	11.07
Pulp, % Sugar	0.47	0.39	0.34	0.40
% Ash Elimination	15.0	12.9	13.5	12.6
% Non-Sugar Elimination	19.8	15.7	16.0	16.0
% Amine-Compound Elimination	30.7	35.8	36.2	36.0
% Invert Elimination	52.8	50.0	41.7	49.1

[1] Temperature in diffuser after first 15 percent of cossette travel.
* Low brix due to steam dilution.

Table 7 represents a series set up to test the possible benefits of steam prescalding of cossettes on assisting non-sugar elimination. The previously determined optimum of variable temperature diffusion is included in the series for comparison. The prescalding runs demonstrate non-sugar eliminations inferior to the variable temperature diffusion indicating no promise when applied in this manner as a beneficient to over-all elimination. The prescalding results do demonstrate the ability to boost amine elimination. The dilution of the diffusion juice through prescalding is substantial and points up the disadvantage of any direct steam heating employed in diffuser operation.

Table 8.—Use of Pulp Press Water for Diffusion.

Diffusion Conditions:
Beets—In Storage 42 Days, 17.7% Sugar
Draft—150
Retention Time—40 Minutes

	Typical Data for Single Test		
	Diff. Juice from Pulp Press Water	Diff. Juice from Reg. Water	Pulp Press Water
Diffusion Juice Brix	14.15	12.70	0.45
Pulp, % Sugar	0.60	0.31	
% Non-Sugar Elimination	34.5	32.5	
Ash per 100 Sucrose	3.51	3.56	4.21
Amine Compounds per 100 Sucrose	2.25	2.68	6.89
Invert per 100 Sucrose	0.75	0.73	2.03

Table 8 represents a comparative test to examine the effect on non-sugar elimination of returning pulp press water for diffusion. This test is consistent with other repetitions in showing higher purity diffusion juice and higher non-sugar elimination where pulp press water is used for dif-

fusion. While the pulp loss is higher the average of all tests conducted so far show 5.4 pounds of sugar per ton of beets added from pulp press water, compared to 6.2 pounds per ton of beets increased loss of sugar in pulp. We now want to run a similar comparison varying the draft so that more equal pulp losses will occur. In the tests reported in Table 6 straight pulp press water was used for diffusion to accentuate the non-sugar elimination effect.

Table 9.—Draft Variation Tests.

Diffusion Conditions:
Beets—Storage 70 days, 15.0% Sugar
Temperature—85° C. first 15% of cossette travel, 70° C. remainder of diffuser
Retention time—45 Minutes

Averages of 2 Sets of Tests

	Draft 120	Draft 130	Draft 140	Draft 150
Diffusion Juice Brix	13.07	12.22	11.74	11.11
Pulp, % Sugar	0.38	0.23	0.18	0.19
% Non-Sugar Elimination	20.3	17.2	16.0	15.9
% Ash Elimination	16.0	16.2	11.7	14.7
% Amine-Compound Elimination	32.3	28.4	25.5	29.5
% Invert Elimination	46.4	39.1	46.4	39.7

The test work in Table 9 represents a series of tests designed to examine the effects on non-sugar elimination of more completely exhausting the pulp. Factory discussions revolving around this question had persisted for years without a precise answer. Here the opportunity finally presents itself of holding all conditions constant even to the cossettes diffused, with the exception of draft, to vary the degree of exhaustion. The results sharply point up the sacrifice of non-sugar elimination attendant with exhaustion to low pulp levels.

It is hoped that the economic considerations in the forward part of this presentation may assist in pointing the way in balancing considerations of the relative importance of various factors in working toward improved diffusion processes of the future and controlling current diffusers.

While the diffusion studies herein reported are far from complete, it is hoped that they will rouse interest in what may be accomplished in establishing a more sound and factual knowledge of this key unit process of the beet sugar industry.

Investigation of Factors Influencing the Sachs-Le Docte Method

W. D. MACLAY, E. F. POTTER, R. F. ERLANDSEN AND H. S. OWENS[1]

The Sachs-Le Docte (SLD) method of analysis is one of the simplest, most rapid analytical methods ever devised for sucrose. There are two factors which may prevent the determination of a statistically reliable volume of basic lead acetate to be used with a normal weight of beet pulp. These are optically active non-sucrose constituents and the volume of marc. Because of changes in beet varieties and harvesting practices in California during the past 20 years, a technical committee composed of representatives of California growers and processors, the University of California and of this laboratory undertook studies of the determination of the accuracy of the SLD method and the SLD volume, which is now 179.1 ml. for California beets. The first phase of this work was a study of factors influencing the Sachs-Le Docte method. It was carried out by personnel of the Western Utilization Research Branch.

The plan of work for the investigation was to examine the effect of lead acetate on each of the optically active constituents in California beets and then each of the incidental factors, such as heating, solubilization of pulp, etc., which might influence the results. These variables are discussed in the following paragraphs.

Effect of Basic Lead Acetate on Rotation of Sucrose

Bates and Blake (2)[2] measured the change in rotation of a sucrose solution in the presence of increasing concentrations of basic lead actate. Their results are shown in the curve in Figure 1. Our results are similar as shown in the same figure. In measurements of beet juices with a rotation of 13° to 20° S to which are added only the slight excesses of basic lead acetate ordinarily used, the lead error is so small that it is not measurable in the saccharimeter used in this work.

Rotation of Amino Acid Solutions in Presence of Basic Lead Acetate

The marked effect of certain salts on the rotation of many amino acid solutions has been noted in the literature, but no systematic study of the effect of lead acetate on amino acids which occur in beet juice was found. The composition study under way at this laboratory has divulged the amino acids present in California beet juice. The rotations of the more abundant acids in different concentrations of lead acetate are shown in Figure 2. L-asparagine and L-aspartic acid are dextrorotatory in lead acetate while L-glutamic acid, pyrrolidone carboxylic acid, glutamine, leucine, valine, isoleucine and alanine are levorotatory. The combinations of amino acids shown in Table 1 are based upon analyses of diffusion juices from Brighton, Colorado, and Manteca, California (3). The dextrorotatory amino acids are

[1] Western Utilization Research Branch, Agricultural Research Service, United States Department of Agriculture, Albany 6, California.

[2] Numbers in parentheses refer to literature cited.

practically nullified by the levoratatory acids as reported in Table 2, so that the ionic optically active compounds in beet juice have only a small effect in the SLD volume.

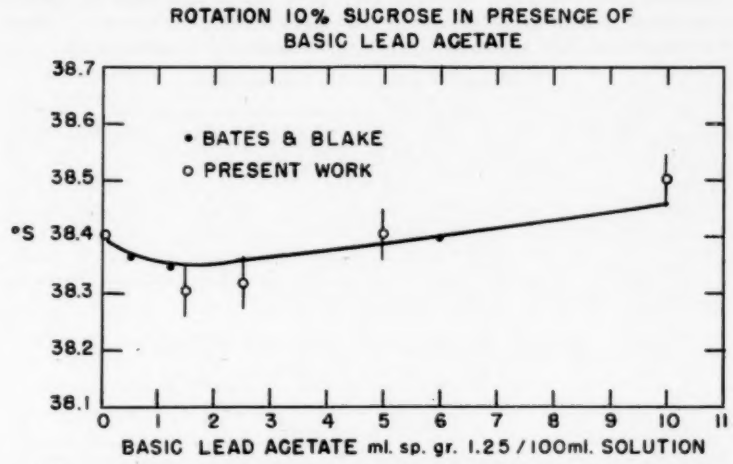

Figure 1.—Effect of basic lead acetate on rotation of sucrose solutions. (10 ml. of 1.25 sp. gr. lead solution per 100 ml. is equvialent to a 5° Brix concentration of basic lead acetate.)

Table 1.—Amino Acid Mixtures Typical of Sugar Beet Juices.

Solution	I (Calif.)	II (Colo.)
	(mg./liter, 10% sugar basis)	
L-alanine	75	40
L-aspartic acid	80	10
L-glutamic acid	130	60
L-glutamine	970	485
L-isoleucine	60	30
L-leucine	50	30
L-serine	50	25
L-threonine	50	25
L-valine	40	25
L-malic[1]	200	200

[1] Optically active nonamino organic acid.

Table 2.—Effect of Basic Lead Acetate on Rotation of Amino Acid Mixtures[1] in 10 Percent Sucrose Solution.

Vol. of the lead acetate solution	0	1	2	5	10	20
I $\Delta°$ S[2]	—0.05	+0.18	+0.15	—0.12	—0.10	—0.20
σ	0.05	0.09	0.04	0.11	0.10	0.18
II $\Delta°$ S	—0.03	+0.08	—0.10	—0.16	—0.13	—0.10
σ	0.05	0.06	0.09	0.11	0.08	0.11

[1] Amino acid mixtures are shown in Table 1.
[2] S = 76.8° for 10 percent sugar solution.

Inasmuch as the SLD method as applied in California calls for hot digestion, both sucrose and sucrose plus amino acid solutions were heated at 80° C. for 30 minutes with basic lead acetate and the optical rotation measured. The unheated solutions like those in Table 2 had an optical rotation of 76.9° S in 5° Brix basic lead acetate solution and one of 76.9° S in heated 5° Brix lead solution. No difference was obtained.

Rotation of Beet Marc Constituents

Of the water-soluble constituents in beet marc, pectin has a specific rotation sufficiently high to effect the SLD method. To test this hypothesis one gram each of marcs previously extracted free of sucrose (No. 123, 170 in Ref. 4) was heated in 100 ml. of water at 80° C. for 30 minutes. The average rotation of the lead-free solution was + 0.8° S. In the presence of 5° Brix lead acetate under the same conditions, the rotation was + 0.04° S. These results can be explained by assuming that a small amount of pectin is extracted by water but is precipitated by the basic lead ion. Saponin, present in fresh pulp, would act like pectin.

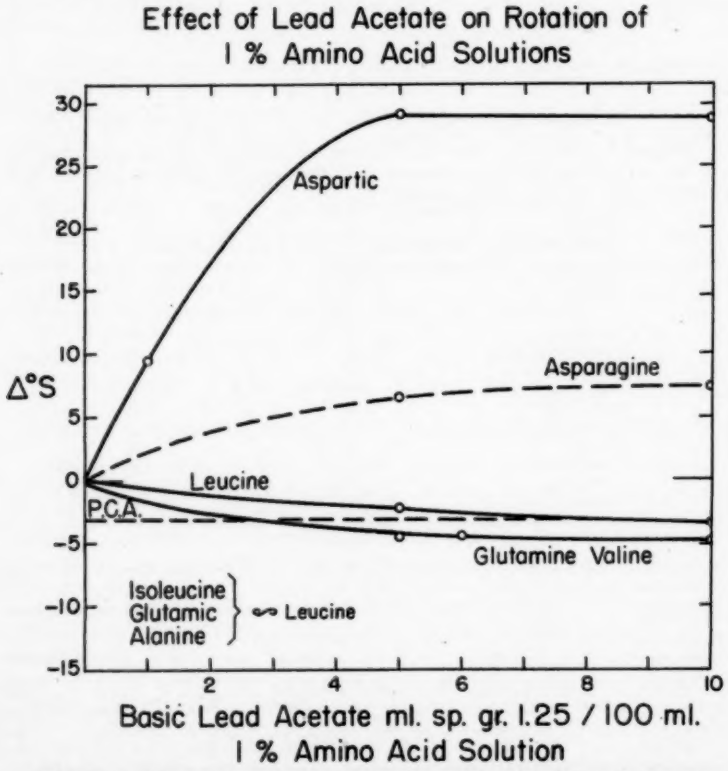

Figure 2.—Change in rotation of amino acids with increasing concentrations of basic lead acetate.

Comparative Sugar Analyses

The results obtained to this point strongly suggest that the SLD method can provide a reliable measure of the sucrose content of beets. The next step was to compare the results obtained by the SLD method and an official AOAC method (1) when applied to a series of beet pulps. These pulps were regular samples prepared and weighed by factory chemists at various tare laboratories. The samples were weighed into friction top 8-ounce tin cans, frozen and transported in the frozen state to this laboratory. They were extracted with 179.1 ml. of 5° Brix basic lead acetate solution at 80° C. for 30 minutes without being removed from the cans. After filtration and adjustment to 20° C. the optical rotation was measured. A portion of the filtrate was deleaded, the sucrose hydrolyzed in acid solution, and total sugars measured by the Munson-Walker method (1). Four of the samples were also analyzed for invert sugar before hydrolysis. There was only 0.04 percent invert in the samples analyzed. The average sucrose content of 36 samples of beets was 15.65 percent by polarization and 15.75 percent by the AOAC method. The agreement between the two methods is about as good as can be expected between different sugar methods. Another inference that can be drawn is that in California beets the raffinose and invert contents are small.

Volume of Marc

The other factor which must be evaluated to make the SLD valid is the volume of marc or volume of juice in the normal weight of beets. One of the most direct ways of doing this is to follow the Daeschner-Bauer modification of Krocker's method (5). The details of this method were provided by Paul Alston of the Spreckels Sugar Company and are as follows.

The sawed or rasped pulp is carefully mixed and a normal weight of the mixed sample is placed in each of six friction top cans or SLD crucibles. To three of the samples is added 179.1 ml. (this may be any known volume near 180 ml.) of 5° Brix basic lead acetate solution and to three others 179.1 ml. of 5° Brix to which was added 10 percent sugar. The six samples are extracted in the usual way and filtered, and the optical rotations measured. The same volume of 10 percent sugar in basic lead acetate solution used above (179.1 ml.) is diluted to 200 ml. and measured in the saccharimeter. The true SLD volume is given by the equation:

$$V = 379.1 - \frac{200\,P_1}{P_2 - P_3}$$

where P_1 is the rotation of the sugar solution, P_2 the rotation of the beet juice plus added sugar, and P_3 the rotation of the beet juice in basic lead acetate without added sugar.

Measurements by this method were undertaken during the past campaign in six tare laboratories as well as our own and will be continued during the next campaign. Results of this cooperative undertaking will be released at a later time when the effect of different seasons can be evaluated.

A second method is to measure the weight of marc in a normal weight of beets. If this weight is subtracted from 26 g., the weight of juice is obtained and that weight can be converted to volume of juice by dividing

by its density. Marc determinations under way at this laboratory show an average of 4.7 percent for 85 inbred varieties. Use of this figure leads to an SLD volume of 176.8 ml. The calculated average for the SLD volume includes a correction for the fact that a low marc beet is likely to be low in sucrose (4), but it does not correct for water of hydration. Scatchard (6) measured hydration of sucrose in aqueous solution and concluded that about one water molecule per polar group in sucrose was held fairly firmly by the sucrose molecule. Most of the marc is carbohydrate in nature and if one molecule of water is "bound" by each polar group, the water of hydration would be between 20 and 30 percent. This would require a correction of about 0.4 ml. in the SLD volume. We have been unable, however, to detect a change in the rotation of sucrose solutions when marc is added to them sufficient to require a correction of this magnitude.

Corrections for Neutral, Optically Active Constituents

California sugar beets generally are low in raffinose and no correction appears to be necessary for it at the present time. If, however, 0.05 percent of raffinose were present, a correction factor might become necessary, because the specific rotation for raffinose, in the absence of basic lead acetate, is 124°, while that for sucrose is 66.5°. This means that, for every 0.05 percent of raffinose, the SLD volume would be increased by 0.9 ml.

In summary, the factors which might affect the accuracy of the SLD method have been examined, and it is concluded that the method is accurate when applied to California sugar beets. The Daeschner-Bauer modification of Krocker's method appears satisfactory for the determination of a statistically reliable volume to be used in the SLD method.

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Factors Affecting the Determination of Sugar in Beets by the Sachs-Le Docte Method

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Several variations in the procedure for the determination of sugar in beets by the Sachs-Le Docte method have been developed by various beet sugar companies in the United States and in Europe. In this paper a study of some of these procedures is reported.

The basic Sachs-Le Docte method is as follows: 26 g. finely rasped beet pulp is weighed into a capsule and a volume of dilute basic lead acetate solution added sufficient to produce a final volume of 200 ml. of the solution in which the sugar is dissolved. The capsule with the contents is allowed to stand with occasional shaking for 20 to 30 minutes, the contents poured on a dry filter and the filtered solution read in a 400-mm. tube. If cold digestion is employed, very finely divided pulp such as is produced by a properly made Keil disc must be used. If hot digestion (80° C.) is used, the pulp need not be quite as fine. Estimates of the proper amount of dilute lead solution to add in the Sachs-Le Docte method range from 177.0 ml. as prescribed by Sachs-Le Docte to 179.1 ml. as prescribed by Bachler (1)[2].

The problem of determining exactly the volume of dilute basic lead solution to add in the Sachs-Le Docte method involves determining the volume of solution contributed by 26 g. of beet pulp. Approaching the problem by various methods, which will not be described here, values have been found as follows:

	ml.
Sachs-Le Docte	23.0
Spengler & Brendel (2)	21.8
Stanek & Vondrak (3)	21.8
Fremel (4)	22.0
Muller & Pucherna (5)	22.0
Bachler (1) and (1a)	20.9 and 21.6
Hartmann & Lewon (6)	20.7

Bachler attributes some of these differences to variations in beets.

Hartmann (6) compared the polarization of beets determined by the Sachs-Le Docte method (hot digestion using volumes of dilute lead solutions ranging from 175 to 182) with the polarization obtained by an extraction method devised by him. In this method 26 g. of beet pulp are diluted with about 50 ml. of solution containing 5 ml. of basic lead acetate solution (55 Brix), transferred to a Soxhlet extractor and extracted under reduced pressure until all the sugar is removed from the insoluble lead-marc precipitate. The extract after cooling is made to 200 ml. and read in a 400-mm. tube. A small amount of ammonium hydroxide is added to the extraction capsule before heating to prevent inversion of sugar. Assuming

[1] Director of Research and Chemical Control and Chief Chemist, (Longmont, Colorado), Great Western Sugar Company, respectively.
[2] Numbers in parentheses refer to literature cited.

that the results obtained by the extraction method are correct, the volume of 3° Brix lead solution to add in the hot Sachs-Le Docte method was found to be 179.3 ml.

Experimental Work

In the work reported here, the extraction method of Hartmann has been compared with the cold Sachs-Le Docte method using 177 ml. the hot Sachs-Le Docte method using 177 ml., and two Pellet methods (201-ml. flask) differing only in that lead acetate was added before digestion in one case and after digestion in the other. In the final series of tests a large sample of beets was taken from the picking table at the Longmont factory each day for 50 days, the sample rasped and the sugar content determined immediately by the five methods. Great care was taken in the preparation of samples and in the analytical work. Pipettes and flasks were carefully calibrated. Five or more polariscope readings were made on each solution. Brix of dilute lead basic lead acetate solution was 2.15. The results of this series of tests are given in Table 1. The averages of the 50 determinations by each of the five methods are as follows:

	Average Percent Sugar
Soxhlet Extraction	17.33
Cold Sachs-Le Docte (177 ml.)	17.32
Hot Sachs-Le Docte (177 ml.)	17.45
Pellet (Lead added before digestion)	17.44
Pellet (Lead added after digestion and cooling)	17.38

The hot Sachs-Le Docte method employing 177.0 ml. dilute lead solution gave results higher than the Soxhlet extraction method by 0.124. Assuming the Soxhlet extraction method to be correct, the volume of dilute lead which should have been added in the hot Sachs-Le Docte procedure, to give the result obtained by the extraction method, may be calculated as follows:

Let x = additional lead solution which should have been added

$$\frac{(200 - x)}{200} \quad (17.446) = 17.326$$

$$x = 1.4$$

The correct volume of dilute lead in this case was found to be 177.0 + 1.4 or 178.4, a value 0.9 ml. lower than that obtained by Hartmann. The

Table 1.—Percentage of Sugar in Beets Determined by Different Procedures.

Colorado Beets					
		Sachs-Le Docte		Pellet 201.0 ml. Flask Lead Added	
Sample Number[1]	Soxhlet Ext. (1)	Cold Digestion 177 ml. (2)	Hot Digestion 177 ml. (3)	Before Digestion (4)	After Digestion (5)
1	18.79	18.52	18.79	18.90	18.65
2	17.00	16.95	16.92	17.13	17.15
3	17.98	18.05	18.21	18.31	18.18
4	17.69	17.80	18.16	17.90	17.90
5	18.99	19.15	19.32	18.93	19.20
6	18.27	18.17	18.39	18.34	18.22

Table 1.—Continued

Sample Number[1]	Soxhlet Ext. (1)	Sachs-Le Docte Cold Digestion 177 ml. (2)	Sachs-Le Docte Hot Digestion 177 ml. (3)	Pellet 201.0 ml. Flask Lead Added Before Digestion (4)	Pellet 201.0 ml. Flask Lead Added After Digestion (5)
7	18.78	18.62	18.81	18.85	18.65
8	20.05	19.72	20.01	20.06	19.99
9	18.65	18.70	18.64	18.60	18.70
10	14.14	14.18	14.29	14.26	14.24
11	19.96	19.86	20.02	19.97	19.97
12	15.63	15.50	15.72	15.70	15.68
13	16.04	16.00	16.10	16.09	16.02
14	15.30	15.20	15.30	15.32	15.29
15	14.58	14.49	14.59	14.59	14.57
16	17.24	17.14	17.27	17.22	17.26
17	15.36	15.40	15.50	15.51	15.49
18	16.98	16.99	17.19	17.09	17.11
19	18.35	18.28	18.40	18.42	18.38
20	17.90	17.95	18.00	18.05	17.97
21	16.86	16.85	16.99	17.01	16.94
22	17.35	17.27	17.44	17.43	17.33
23	13.98	14.01	14.17	14.16	14.09
24	16.35	16.39	16.50	16.50	16.45
25	16.65	16.60	16.70	16.70	16.65
26	16.38	16.25	16.36	16.41	16.32
27	14.86	14.90	15.00	15.00	14.94
28	18.89	19.09	19.15	19.15	19.12
29	15.29	15.40	15.50	15.52	15.42
30	17.29	17.31	17.44	17.42	17.33
31	15.94	16.01	16.09	16.08	16.03
32	17.51	17.61	17.69	17.70	17.63
33	16.89	16.99	17.10	17.09	16.98
34	15.35	15.39	15.53	15.54	15.41
35	18.69	18.70	18.81	18.81	18.73
36	17.50	17.55	17.65	17.65	17.57
37	18.99	19.00	19.09	19.09	19.01
38	17.77	17.90	17.99	18.00	17.90
39	16.97	16.90	17.00	17.01	16.95
40	18.86	18.86	18.90	18.91	18.87
41	18.17	18.23	18.39	18.40	18.21
42	16.35	16.40	16.45	16.45	16.40
43	18.33	18.52	18.59	18.59	18.54
44	18.89	18.90	19.04	19.04	18.92
45	16.93	16.95	17.03	17.02	16.93
46	17.70	17.70	17.79	17.80	17.72
47	17.82	17.81	17.92	17.93	17.81
48	17.66	17.64	17.76	17.77	17.66
49	17.98	18.00	18.11	18.10	18.01
50	20.40	20.39	20.50	20.49	20.39
Mean	17.326	17.324	17.446	17.440	17.378
		(2-1)	(3-1)	(4-1)	(5-1)
Stand. Dev. of Difference		.101	.157	.141	.097
Stand. Dev. (Mean) of Difference		.014	.022	.020	.014

[1] Samples taken daily between October 15 and December 22, 1953, hence sample number indicates approximately the date of sampling.

standard deviation of the mean difference between results by the hot Sachs-Le Docte method and results by the Soxhlet extraction method is .022. The calculated volume of dilute lead solution therefore may lie between 178.2 and 178.6.

Osborn (7) in a paper read before this society in 1946 discussed the Pellet method for the determinations of sugar in beets. He concluded that, in the Pellet method, basic lead acetate solution should be added after digestion and that the volume of flask should be 201.0 ml. The volume of marc plus lead precipitate according to him is 1.0 ml. This value is based on many determinations using the R. J. Brown (8) method. Using a similar method, the value of 1.0 ml. for the volume of marc plus lead precipitate has again been confirmed (see Table 2). The Brown method, in effect, denies the possibility of so-called "Water of Imbibition" or "Colloidal Water" in the insoluble matter. Any water contained in the marc or lead precipitate, according to Brown, is the same as the water in the bulk of the solution and carries the same concentration of sugar and other substances in solution.

Results of polarizations obtained in these investigations throw doubt on Brown's assumptions. Table 2 shows that the Pellet method using a 201.0 ml. flask gives results almost exactly 0.05 ml. higher than those obtained by the Soxhlet extraction method. This corresponds to an error in volume of 0.6 ml. The correct volume of Pellet flask under these conditions appears to be 201.6 ml. instead of 201.0 ml.

An unexpected confirmation of the difference between the Pellet hot digestion—201.0 ml. flask method and the Sachs-Le Docte method (cold 177 ml.)—was obtained in the beet laboratory at the Longmont factory this year where checks of the regular beet laboratory determinations are made frequently by the Pellet method. The averages of 93 determinations made during the receiving season show results to be high by 0.05. In 1952, the difference between results by the Pellet method (201.0 ml. flask) and by the Sachs-La Docte (cold, 177 ml.) method was found to be 0.04.

According to Bachler, beets from California with normally high sugar content and relatively low purity require a larger volume of dilute lead acetate in the Sachs-Le Docte method than was prescribed by Sachs-Le Docte. A few tests were made by us on California beets furnished by the Spreckels Sugar Company. These beets were harvested in April, 1953, and were much lower in sugar content than normal and may not have been typical of California beets. The results are shown in Table 3. The averages of the 16 determinations by each of four methods are as follows:

	Percent Sugar
Soxhlet Extraction	13.24
Cold Sachs-Le Docte (177 ml.)	13.24
Hot Sachs-Le Docte (177 ml.)	13.33
Pellet (201 ml. lead added after digestion)	13.29

In this series of tests, as in the previous series, results by the hot Sachs-Le Docte method (177 ml.) were found to be higher than those obtained by the Soxhlet extraction method. Upon correcting results by the hot Sachs-Le Docte (177 ml.) to a volume of 178.4 ml., the average polarization is reduced to 13.21, a value .03 below that obtained by the extraction method but probably within the limit of error in this short series of measurements.

Table 2.—Marc and Lead Precipitate from Soxhlet Extraction.

Number Sample	of Marc. Weight	Sp. Gr.	and Pb PPt Volume of Marc.
1	2.90	2.6412	1.09
2	2.82	2.5714	1.09
3	2.75	2.5927	1.06
4	2.75	2.5263	1.09
5	3.20	2.2972	1.39
6	2.40	2.6275	0.91
7	2.94	2.5878	1.14
8	2.89	2.3606	1.22
9	2.59	2.4031	1.08
10	2.42	3.0834	0.78
11	2.99	2.4707	1.21
12	2.45	2.6821	0.91
13	2.93	2.7620	1.06
14	2.39	2.8538	0.84
15	2.78	2.7334	1.02
16	2.50	2.6179	0.95
17	2.93	3.2719	0.89
18	2.95	2.7306	1.08
19	2.69	2.7103	0.99
20	2.83	2.5550	1.11
21	2.33	2.2875	1.02
22	2.61	2.5810	1.01
23	2.90	2.8805	1.01
24	2.90	2.7420	1.07
25	2.90	2.5784	1.02
26	2.62	2.7923	0.90
27	2.50	2.6559	1.04
28	2.75	2.7167	1.12
29	2.72	2.8385	0.93
30	3.05	2.8866	0.94
31	2.63	2.6312	1.02
32	2.69	2.6349	1.15
33	3.02	2.6600	1.07
34	2.85	2.8430	1.12
35	3.17	2.6108	1.15
36	3.00	2.6855	1.09
37	2.82	2.2736	1.24
38	3.12	2.7697	1.24
39	2.88	2.7228	1.06
40	3.07	2.5797	1.19
41	3.21	2.6610	1.21
42	3.02	2.7332	1.10
43	3.07	2.6275	1.17
44	3.21	2.6982	1.19
45	2.57	2.6177	0.98
46	3.00	2.7461	1.09
47	2.93	2.6585	1.10
48	3.08	2.5894	1.19
49	3.30	2.7616	1.19
50	3.07	2.6275	1.17
Mean	2.84	2.6634	1.07

The average percent sugar determined by the Pellet method (201 ml.) flask in these tests on California beets was higher than that obtained by the extraction method by 0.04, indicating that the volume of Pellet flask—201 ml.—used in these tests is too low by about 0.4 ml.

A few tests were made to determine the effect of the concentration of lead on results obtained by the Sachs-Le Docte method. Results are shown in Figure 1. The effect is somewhat greater in the case of the hot digestion Sachs-Le Docte method than in the case of the cold digestion method, but in both procedures the polarization of beets is depressed by 0.05 to 0.07 for each 1° increase in Brix of lead acetate solution.

Conclusions

Results of the tests reported in this paper show that sugar in beets determined by the Sachs-Le Docte method using 177 ml. of 2.15 Bx lead acetate solution with cold digestion agrees closely with that obtained by the Sachs-Le Docte method using 178.4 ml. and hot digestion. Sugar determined by these procedures also agrees closely with that obtained by Hartmann's Soxhlet extraction method.

Assuming that the Soxhlet extraction procedure gives the correct content of sugar in beets, the volume of flask used in the Pellet method for the determination of sugar in beets should be 201.6 ml.

The Brix of lead solution used in the Sachs-Le Docte method should be closely controlled. An increase of 1° Brix of lead solution in the range 2° to 8° Brix reduces the polarization of beets by .05 to .07.

Table 3.—Percentage of Sugar in Beets Determined by Different Procedures.

California Beets				
		Sachs-Le Docte		
Sample Number	Soxhlet Extn. (1)	Cold Digestion 177 ml. (2)	Hot Digestion 177 ml. (3)	Pellet 201.0 ml. Flask Lead After Digestion (4)
1	16.15	16.07	16.23	16.10
2	15.88	15.83	15.94	15.89
3	16.63	16.72	16.85	16.79
4	17.23	17.30	17.42	17.38
5	17.07	17.02	17.12	17.05
6	16.51	16.53	16.61	16.52
7	16.50	16.55	16.61	16.50
8	15.60	15.78	15.76	15.59
9	10.31	10.30	10.23	10.46
10	10.23	10.23	10.23	10.27
11	10.14	10.17	10.17	10.09
12	10.30	10.27	10.44	10.43
13	9.82	9.81	9.87	9.89
14	10.01	9.96	10.11	10.04
15	9.88	9.87	10.02	10.03
16	9.66	9.50	9.65	9.63
Mean	13.24	13.24	13.33	13.29
		(2-1)	(3-1)	(4-1)
Stand. Dev. of Difference		.077	.115	.287
Stand. Dev. (Mean) of Difference		.019	.029	.072

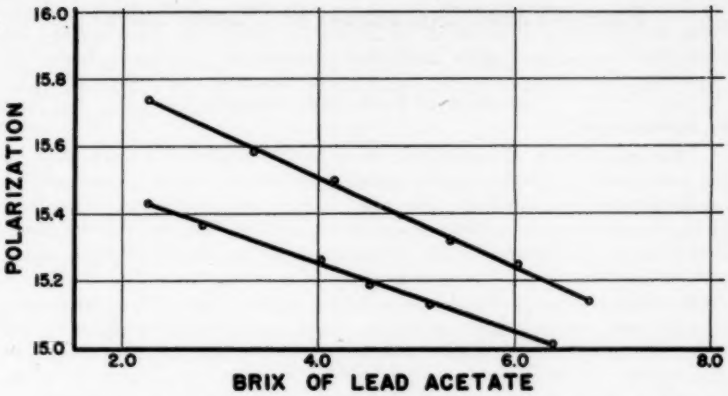

Figure 1.—Effect of Brix of basic lead acetate solution on polarization of beets. The two curves were made on different samples.

ACKNOWLEDGMENTS

The authors are indebted to Clarence Leonard, assistant chemist, Longmont factory, Great Western Sugar Company, and Nobel Ida, a student at the University of Colorado, temporarily employed at the Longmont factory, for most of the analytical work reported in this paper.

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Round-Table Discussion of "Lime Salts"

R. A. McGinnis[1], Moderator

Summary of Preliminary Remarks

A. Introduction

The purification of sugar-beet juices by the use of lime dates back to the early part of the nineteenth century, and the corollary use of carbon dioxide to only slightly later. In spite of repeated challenges—many hundreds of substances have been proposed for this use—this is still the standard method: the consequence of its strong advantages of effectiveness, cheapness and convenience. Its most important disadvantage is "lime salts."

This is an attempt to summarize the classical view of lime salts, and to point out problems and anomalies. In its preparation we have leaned heavily on the published works of Prof. J. Dedek, whose paper given before this Society in 1948 is the great classic in this field (1)[2].

B. Definition

Lime salts are soluble calcium salts which carry through to the sugar end of the factory. The plurality of the term must be kept in mind, to avoid the seemingly inexplicable.

C. Harmful Effects of Lime Salts

1. Scale formation in heaters and evaporators.
2. Retarded juice boiling in evaporators and vacuum pans.
3. Increase in molasses produced.
4. Lowering of white sugar quality through:
   a. hygroscopicity of ash
   b. turbidity of sugar solutions.

D. Nature and Source of Lime Salts

1. From Healthy Beets.

These lime salts are not susceptible to control by the factory operator. Most of the substances listed are probably present in the beets as potassium or sodium salts. Among (a) aliphatic acids is found chiefly malic acid. (b) Amino acids are represented chiefly by glutamic, aspartic, and pyrollidone carboxyllic acids. These acids form calcium complexes, of the type $CaAn^+$, and will compound with carbon dioxide as carbaminates, which, in turn, may slowly change to carbonates. (c) Betainates may be created, as well as (d) proteinates. The latter are surface active and generally un-ionized.

$$CO_2 + R-NH_2 = R-\overset{H}{\underset{|}{N}}-\overset{O}{\overset{\|}{C}}-OH$$

2. From Fermentations.

A considerable degree of control can be had over lime salts from this source. These lime salts represent double damage, since their formation

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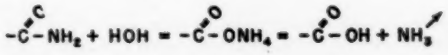
[2] Numbers in parentheses refer to literature cited.

usually involves destruction of sugar. The fermentations may occur in (a) stored beets, as a result of enzymatic or micro-biological action, and (b) in dilute factory juices such as raw juice. The products of fermentation are generally acidic in the earlier stages, and are represented chiefly by lactic and acetic acids.

3. From "Unavoidable" Destruction Reactions.

These occur as a result of the conditions in liming-carbonation, such as alkalinities and lime concentrations, high temperatures, and prolonged time intervals. (a) There is always some slight inversion of sucrose, and under certain conditions this may be appreciable. Chemical destruction of invert occurs to some extent in raw juice, and is virtually completed during first carbonation. The actual course of this degradation is very complex, due to the complex chemical environment. It is important to observe that lactic acid is one of the chief products. Most of the products are acids with soluble lime salts, and many are colored.

(c) The saponification of amides has traditionally been considered the most important source of lime salts. The amides in beet juices are mainly glutamine and asparagine. The saponification yields acids, plus ammonium ion or ammonia, depending upon the ambient pH. The reason for the importance of this type of reaction is that to it has been attributed the chief responsibility for:



1. The differences in lime salts content from different types of beets.

2. Thermolabile and thermostable juices.

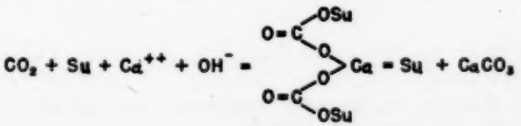
3. Differences in juices which make "vigorous" or "mild" defecation processes appropriate.

4. Decrease in pH in the sugar end. The belief has been current that the amide content of beets is subject to some control through fertilization and irrigation practices.

(d) A fourth source is the occasional degradation of pectin. Some of the smaller galacturonic acid units have soluble lime salts.

4. From Process Reagents, other than Lime.

Carbon dioxide in alkaline solution can combine with sucrose and lime to form alkyl carbonates, which may in time release the sucrose with formation of calcium carbonate. In addition, carbon dioxide takes a part in the formation of carbaminates, as already described.



Sulfur dioxide, when added in large enough quantities, may form appreciable quantities of calcium sulfate, which is somewhat less soluble than the sulfite, and may take an unpleasant part in evaporator scale.

D. Problems and Anomalies

1. Variation with Geographical Region

Mr. Weitz of the American Crystal Sugar Co. submitted data illustrating this effect. At the Oxnard factory, lime salts must be kept under 0.060 percent CaO on dry substance, otherwise the evaporators scale so rapidly that operations cannot continue. In spite of many efforts at reduction, it is here found necessary to use soda ash, sometimes up to 5 lbs./ton of beets. At their Clarksburg factory, lime salts are normally in the region 0.060-0.080 percent, but this figure has gone as high as 1.000 percent while working deteriorated piled beets, without shutting down the factory. At Missoula, lime salts above 0.030 percent make the juices so slow boiling that operation is restricted; heavy scaling is absent. At Mason City, 0.100-0.125 percent is normal for lime salts, with no particular difficulty.

Mr. Rorabaugh of the Holly Sugar Corporation contributed data on their Californi and Rocky Mountain plants, summarized below.

Table 1.—Lime Salts, Holly Sugar Corp. Factories.

	1952	1951	1950	1949
Rocky Mountain Plants	.046	.045	.037	.041
California Plants	.139	.110	.107	.116

Data obtained through interchange between sugar manufacturers in 1949 was classified, and a summary follows.

Table 2.—Summary.

	pH Change				
Region	L. S.	Evaps.	Evaps. to raw fil.	Beet apc	Soda Ash
Midwest	.087	+.1	—.7	86.5	.31
Rocky Mt.	.043	+.5	0	87.4	.34
West Slope	.047	0	0	86.5	.45
Pacific	.107	—.4	—.8	84.8	.65

Differences such as are shown by the data described cannot be understood unless the plural number of "lime salts" is kept in mind.

2. Use of Soda Ash.

The normal method of reducing lime salts in thin juices is by addition of soda ash. There are a number of apparent anomalies in connection with its use, which can be explained by application of simple physical chemistry. By reference to a phase diagram (Figure 1 of reference (1)), it was shown why:

(a) Soda ash can never precipitate equivalent quantities of lime salts.

(b) Different degrees of deliming may be obtained in juices having the same lime salts contents.

(c) Two similar juices, differing only in amounts of lime salts, will show different degrees of deliming with the same soda ash addition.

Through reference to Figure 2 of the same work, it was shown why:

(d) The addition of soda ash sometimes increases instead of decreases scaling.

By the use of Figure 3 it was shown why:

(e) Either an increase or decrease of pH on concentration may be produced, depending whether there is an excess of calcium ion or carbonate ion in the juices. This effect does not involve amides.

MR. ALLAN WOODS, Union Sugar Co.

At Betteravia we have not been particularly successful in the addition of soda ash to our juices. Our lime salts are not reduced—in fact, we even notice an increase at times. We are wondering if this could come from the fact that we carbonate at higher alkalinity than most factories, thereby reducing the solubility products of the lime salts.

DR. MCGINNIS

General considerations might lead one to believe that if fewer non sugars of a type are present, the solubility products might more closely resemble those in pure water, but any such conclusions would certainly be tenuous.

MR. BLANKENBACH

We like to use soda ash sometimes when we have high lime salts, but frankly speaking, we never have good results. Lime salts always increase when we add soda ash. We are wondering what we are doing that is different from other factories.

MR. WOODS

Our average alkalinity is about .090. We frequently run our alkalinity at 0.100, and with some beets we will go as high as 0.110 and 0.120.

DR. MCGINNIS

If we were able to operate at such alkalinities, we would not complain of lime salts.

MR. FRANK RAWLINGS, Amalgamated Sugar Co.

Hugh Rounds has never found any exceptions to the effective alkalinity concept. This concept offers, first, a rational concept for adding soda ash to a given control outlet. Secondly, it shows the proper second carbonation alkalinity control point for minimum lime salts, which is very sharply defined. If soda ash is not added without this full concept in mind, the effect of its addition can be nullified. Even one or two hundredths deviation in second carbonation alkalinity can increase the lime salts 50 to 100 percent.

DR. MCGINNIS

May I ask Dr. Lucille Hac, of Internationals Minerals and Chemical Corp., to say a few words about organic nitrogen?

DR. HAC

As you know, we produce Ac'cent (monosodium glutamate) from the glutamic acid (GA) present in Steffen's filtrate. I do not believe our material can be responsible for the aforementioned pH drop across the evaporators. Our studies over a period of several years indicate that the potential source of GA in the beet root, itself, is glutamine. In diffusion juice there is roughly 10 percent free GA, 1 to 2 percent pyrrolidone carboxyllic acid (PCA) and the remainder (88 percent) glutamine. Glutamine is a very unstable substance. Acid, alkali, or heat readily convert it, by the elimination of ammonia, into the stable ring compound, PCA.

Essentially all of the glutamine in diffusion juice is usually converted to PCA during carbonation and it continues as PCA throughout the sugar process to the Steffen's heaters. At this point, some hydrolysis of PCA to GA does occur; here roughly 30 percent is present as GA and 70 percent as PCA.

Obviously, if the ratios of both PCA and GA to sugar remain constant in thin juice, thick juice, and molasses, it is unlikely that our material can be blamed for the pH drop across the evaporators.

DR. MCGINNIS

Do these materials go through to the sugar end as lime salts?

DR. HAC

Yes, very probably both GA and PCA are a part of the constituents making up lime salts, but there certainly must be several other substances also. Do you always get all four of the deleterious effects of high lime salts which you pointed out, or do you sometimes have only one or two of the effects?

Could removal of calcium ions from solution; i.e., further precipitation during the evaporation (in the scale or elsewhere) account for the pH drop? Do you find calcium phosphate in the scale? If evaporation causes the precipitation of calcium salts or organic phosphates or other weakly acidic substances, a drop in pH would occur due to the removal of the calcium ions from solution. We have observed such increases in acidity accompanying slow precipitation in the barium hydrolysates of beets and factory juices used for GA determinations.

DR. MCGINNIS

Pacific Coast factories show the greatest pH drop across the evaporators. How do Pacific Coast beets compare with those from other regions in GA content?

DR. HAC

There are wide differences in the GA content of beets grown on the Pacific Coast as well as in other parts of the country. The beets in the Clarksburg, California, area are much higher in GA content than those in the Woodland area, and the high GA content of beets in the Mason City, Iowa, region is well known. You have pointed out that lime salts are a

greater problem at the Woodland factory than at either of the factories with higher GA. On that basis, also, I should assume that GA is not the cause of your troubles.

DR. MCGINNIS

You are correct, of course, in stating that all the adverse effects of lime salts do not occur together. If your thesis is correct, that amides are not responsible for the pH drop, a careful study of the situation is justified. There may be something that can be done to eliminate it.

I would like to make the statement, supplementing Mr. Rawlings' remarks, that we do not use the effective alkalinity concept at the Spreckels factories; in the first place, because our effective alkalinity is too low, and too much soda ash would be required to raise the alkalinity to the optimum point. Secondly, we frequently cannot operate at the optimum second carbonation alkalinity because the pH drop across the sugar end would result in acid crystallizers.

DR. STARK, Western Regional Research Laboratory

I do not recall that there was much pH drop in the Washington factories. But our analyses of their molasses showed an extremely high amount of PCA as compared to the other coast factories, and so I think this should support Dr. Hac's contention.

DR. HARRY S. OWENS, Western Research Laboratory (by correspondence)

According to solubility product calculations there is as much as 1500 times as much Ca ion in thin juice as there should be. There must be a good physical reason or reasons for this. Because solubility of crystals increases with decreasing particle size, particularly near colloidal dimensions, sufficient time must be allowed to permit calcium carbonate crystals to grow to finite size. This source of excess lime salts would lead to scale formation in the evaporators. A second reason depends upon decreased activity of calcium ion because of amino acids, hydroxy acids, and perhaps sucrose. These compounds readily form complexes with calcium at alkaline pH values. If the pH drops during evaporation, this source of calcium could also cause scaling, depending upon the carbonate ion concentration. This second cause of lime salts might be eliminated by use of oxalic acid or sodium oxalate, rather than soda. This is something we may be able to try later on.

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PHYSIOLOGY

The Physiology of the Growth of Sugar Beets

F. W. Went[1]

The sugar beet is, in many respects, an ideal experimental plant. We are primarily interested in its sugar content, and this sugar is the principal product of photosynthesis which does not seem to undergo transformation between its production in mesophyll cells and its storage in root cells. There are no complicating problems concerning the stem, since the leaves are implanted immediately upon the swollen root crown. The greatest disadvantage of beets for physiological experiments is their variability. Most commercial varieties are kept heterozygous to the greatest degree. This results in a degree of variability of both tops and roots, as far as size and form is concerned, which is unparalleled in any other major crop plant. The variability in size of root is not primarily the result of mutual shading and competition. In all other crop plants, heavy stands result in a more uniform, though smaller, size of the individual plants. In young beet plants, long before they start to shade each other or compete for food or water, extreme differences in size occur.

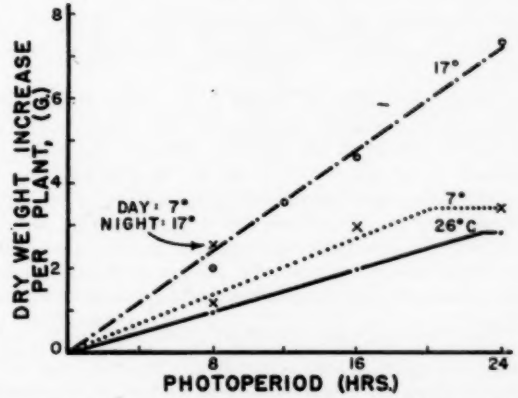

Figure 1.—Gain in dry weight of US 22/3 sugar beet plants in 30 days under different conditions of temperature and photoperiod.

In the experiment shown in Figure 1, plants were grown under a variety of temperature and light conditions. It was found that the greatest variability occurred in plants grown in an 8-hour photoperiod. In four separate groups, the lightest plants were 33, 33, 34, and 34 percent of the weight of the heaviest plants. In the 12- and 16-hour photoperiods, the lightest plants were 38, 50, 51, and 51 percent of the weight of the heaviest. In the plants grown in continuous light, the lightest plants were 55, 61, and 66 percent the weight of the heaviest. This shows that the more optimum the growing conditions, the less the variability. This result might be ex-

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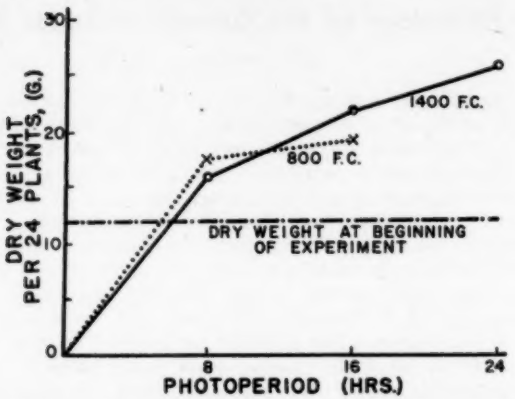

Figure 2.—Average total dry weight of US 22/3 and US 35 sugar beet plants in 7 days at 14° C. under different conditions of light intensity and photoperiod.

pected if the population was very heterogeneous and where, under poor growing conditions, the heterozygosity would become most clearly expressed in differences in growth.

In the experiment shown in Figure 2, the same phenomenon was observed. At the beginning of the experiment, the plants in the two lightest groups weighed 50 percent of the heaviest. When these plants were grown for an additional 7 days at 14° C. in 8-, 16-, or 24-hour photoperiods, the variability slightly increased in the 8-hour, decreased in the 16-hour, and decreased appreciably in the 24-hour photoperiod. This was due to the fact, that in short photoperiods, the slowest growing (or lightest) plants continued to grow slowly. In the long photoperiods, the increase was approximately the same for the light and the heavy plants. Table 1 shows this

Table 1.—Dry Weight of the Heaviest and the Lightest Beets (6 Plants per Container, 4 Containers Each) at the Beginning of the Experiment, and After 7 Days' Growth, for US 22 and US 35.

	Light Intensity	Photo-period	Dry Weight of 24 Beets Each		Increase Dry Weight in 7 Days		Weight Increase of Lightest in Percent of Heaviest
			Heaviest	Lightest	Heaviest	Lightest	
	ft.c.						
At beginning of experiment			15.98	8.05			50
After 7 days	800	8	23.24	11.06	7.26	3.01	41
	800	16	24.48	14.54	8.50	6.49	76
	1400	8	21.95	10.30	5.97	2.25	38
	1400	16	26.91	15.62	10.93	7.57	69
	1400	24	30.21	20.82	14.23	12.77	90

in some detail. The variability of these beets, therefore, depends largely upon sub-optimum growing conditions. Some plants are able to grow very well and make full use of light of short duration, whereas, others do this only during long photoperiods.

The over-all growth of the sugar beet has been studied in detail by Ulrich. The differences in response which he observed under different temperature and light conditions, must all find an explanation in the basic responses of beet plants to temperature and light. Their total growth is the sum total of all reactions going on in the plant. In this paper, an attempt is made to differentiate between the various physiological processes which contribute to the growth of the beet.

Photosynthesis will be considered first. Under ideal conditions of light and temperature, the photosynthetic efficiency of beets is about 10 percent. This means that 10 percent of the incident light can be transformed by the beet leaf cells into chemical energy. In the field, not more than one or, at most, two percent of the light energy is transformed into harvestable plant material. This seems to indicate that it is not photosynthesis, as such, which limits dry-weight production in the field. For closer analysis of the photosynthesis of beets, the effects of light on the increase in dry weight of young beets just before they are starting to thicken their tap roots were measured. To this end, young beets were germinated or transplanted in containers with vermiculite.

In the earlier experiments, five plants were grown together in a 10 x 10 centimeter plastic container. Since this technique tended to increase the individual variability, beets were grown singly in plastic cups 7 centimeters in diameter in later experiments.

Before the start of the experiment, all 100 or more containers with beets were lined up and visually divided into equal groups, each group containing the same proportions of heavy and light plants. One or two groups were harvested immediately, the other groups being kept for six or more days at different temperatures, different light intensities, or different photoperiods before being harvested. The increase in dry weights during that period of exposure can then be calculated by differences. Figures 1 and 2 show the gain in weight of different beet varieties over 7- and 30-day periods in 8-, 12-, 16-, and 24-hour photoperiods. It can be seen that there is a direct proportion between duration of illumination and dry-weight production probably indicating that photosynthesis is limiting. No increase in dry weight was noticed when light intensity was increased to above 1000 foot-candles, from which it can be concluded that the photosynthetic process cannot proceed faster than this rate. Only the rate of the process is limited, not the amount of dry weight which can be produced. By increasing the duration of illumination, more dry weight is produced in proportion to the length of photoperiod. It might be concluded, that at a 1000 foot-candle intensity, an equilibrium is reached between the rate of formation of photosynthates and their translocation out of the leaf cells. This limited rate of translocation could either be due to the translocation system itself, or to the size of the receiving end of the translocation system. If there is not enough space to store the photosynthates, the translocation system will become clogged and the rate will decrease.

In a cooperative experiment with Dr. John Spikes and Mr. Bruce Burnham of the University of Utah at Salt Lake City, beets were grown under several different growing conditions. After the plants had grown for four weeks, half were harvested and the material sent to Dr. Spikes for biochemical analysis. The remainder of the plants were divided into two groups and were subjected to light at intensities of 800 and 1400 foot-candles at 17° C. in a 24-hour photoperiod and harvested following one week's growth. From the increase in weight during the last weekly period, it was possible to get an idea of the growth potential of the beets which previously had been subjected to different temperatures and photoperiods.

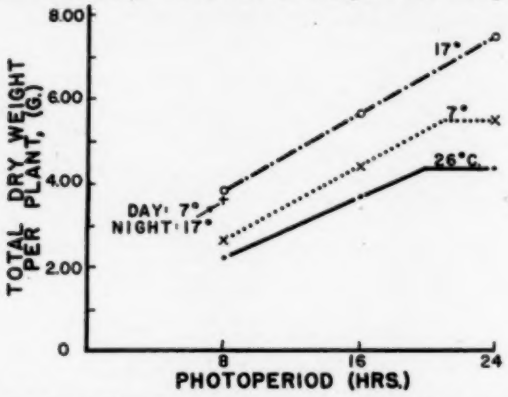

Figure 3.—Total dry weight of US 22/3 sugar beet plants after 7 additional days at 17° C. under a 24-hour photoperiod (temperature and photoperiod figures in graph refer to previous treatments).

Thus, correlations could be made between individual processes and previous or subsequent growth. Figure 1 shows the relationship between length of photoperiod and amount of dry weight produced. It can be seen that at 17° C., approximately twice as much growth and dry weight was produced than at either 7° C. or 26° C. The plants which had been grown at an 8-hour photoperiod had a greater growth potential than those at 16- or 24-hour photoperiods, as seen by comparing Figure 1 and Figure 3. Results seem to indicate that during short photoperiods, the plants had been held back in dry-weight production by the amount of photosynthates formed. As soon as more were formed in a 24-hour photoperiod the plants gained weight at an accelerated rate. The plants which previously had been at 26° C. photosynthesized better in a 1200 foot-candles than a 600 foot-candles intensity, whereas, the plants from 17° C. to 7° C. were more efficient in growth at the 600 foot-candles intensity.

Concerning correlations between individual processes and growth, Figure 4a shows that the rate of the Hill reaction in beet leaves is positively correlated with length of photoperiod under which plants were grown. Conversely, Figure 4b shows that there is a negative correlation with the growth potential of the beets. It could be concluded that the photochemical reduction of water inside the chloroplasts is not the limiting process in the growth

of beets. On the other hand, there is a slight positive correlation between the respiration rate of leaf discs and subsequent increase in weight. Plants with a high respiration rate were, in general, those which grew most rapidly when brought under the same conditions.

In another experiment, three different beet varieties were grown under different temperature conditions. Under optimum temperature conditions, slightly more growth was noticed in the 750 foot-candles light intensity. Figure 5 shows the results of this experiment in which the values for both 750 foot-candles and 1200 foot-candles have been plotted. From these figures it seems that GW 304A performed slightly better than US 22/3, especially at the lower temperatures. Variety 492 was less responsive than either of the other varieties.

The results of the experiment just described differ from those reported by Ulrich. He found that in artificial light intensities of 1000 to 15000 foot-candles, beets grew inferior to those grown in full daylight in the greenhouse. The basis for the difference in results probably lies in the fact that leaf development in older beets is so great that the leaves shade each other sufficiently to prevent each leaf from receiving the maximum light intensity, rather than the age of the plant. The majority of the older plants in a greenhouse get only one-fifth to one-tenth of the total amount of available light. Older beet plants, therefore, require a much higher light intensity for saturation, not because the saturation of the individual leaf is at a higher intensity but because the average light intensity at each leaf is so much lower. We could draw from this consideration, the conclusion that beyond a certain density of foliage, no advantage is gained by the beet plant from the development of a larger leaf area.

Some experiments on sugar translocation in the sugar beet have been carried out by Hull (1953). He found that at low temperatures, more

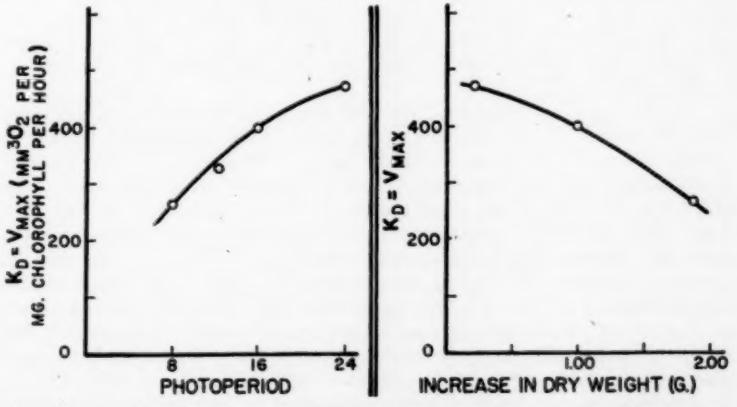

Figure 4a (left).—V_{max} of Hill reaction in leaves of US 22/3 sugar beets as a function of photoperiod. (after John D. Spikes).

Figure 4b (right).—V_{max} of Hill reaction as a function of increase in dry weight of the plants.

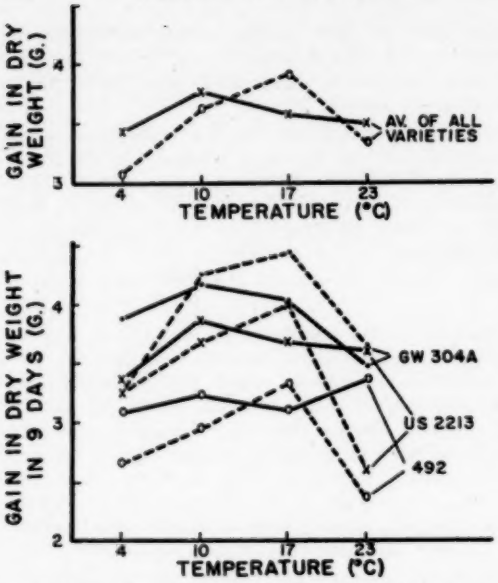

Figure 5. — Gain in dry weight per plant of 3 varieties of sugar beets under different conditions of temperature and light intensity (broken lines —650 to 700 foot-candles, solid lines—1200 to 1500 foot-candles.

(US 2213 in adjacent figure should be US 22/3)

sugar is translocated from the leaves to the root system. This probably explains Ulrich's observation that at lower temperatures, the sugar percentage of beets increases. The lower the temperature, the more sugar is moved out of the leaves into the root. This leads to the conclusion that optimum sugar production can be obtained by first having the beets grow at a maximum rate, so that as much storage space is produced as possible. This happens at fairly high temperatures which normally occur during summer in the beet growing areas. Shortly before harvest, beets should be allowed to grow at lower temperatures so that the roots formed during summer can be filled with sugar.

In the previous discussion, we have seen how photosynthesis partially depends on the size of the root where the formed photosynthates can be stored. What do we know about the factors controlling this root growth? Unfortunately, the answer must be rather negative. We know very little about the physiology of the growth in size of the sugar beet root. It is obvious from Ulrich's determinations that root growth stops when both temperature and nitrogen supply in the soil become low. There is currently no contrary evidence. Hormones coming from the leaves apparently do not control the size growth of young sugar beet roots. This suggestion is made as a result of experiments by Luis Gregory on potatoes. He found that tuber production of potatoes results from the influence of a factor produced in the tops of the potato plant at night temperatures below 23° C. It is possible that a similar substance is formed in beet leaves which causes enlargement of the primary root. This substance apparently is formed only in older leaves. Grafting experiments should be used for this study, If it were possible to identify this factor with a chemical (which could be synthesized), great new possibilities for increased sugar production would be available.

Growth and Development of Sugar Beet Plants at Two Nitrogen Levels in a Controlled Temperature Greenhouse

ALBERT ULRICH[1]

The growth and development of sugar beet plants has been of interest to many research workers and to numerous beet growers for many years. The results of the investigations by Bouillenne, Kronacker, de Roubaix (3)[2], and Bakhuyzen (1), have generally agreed that under field conditions, the beet plant, during the first season, goes through a leaf development stage, a period of storage root formation, and finally a "ripening" stage. Watson and Selman (8) concluded from their growth studies, however, that "there is no clear distinction between phases of growth and of storage in the root, for the young roots have already a high sucrose content, so that growth and sucrose storage proceed together." During the second year's growth, providing intervening temperatures are neither too low nor too high and are of sufficient duration, beet plants flower readily, especially at cool temperatures and long photoperiods [Owen, Carsner, and Stout (5), Stout (7), and Banga (2)]. To the grower and the processor, these events in the life cycle of the beet plant are important, since it is essential to know when beets are "ripe" enough to harvest for sugar manufacturing or in the proper environment for seed formation.

On the basis of experimental results obtained recently in controlled environment facilities (11), the growth and development of sugar beet plants appear to be closely related to the sucrose economy of the beet plants, namely, sucrose formation and utilization. The sugar formed first by the beet leaves is used to maintain the basic metabolic processes of the plant, and as more sugar is produced, it is used to form more leaves and more fibrous roots. After these requirements have been met, the sugar formed is used to increase the sucrose concentration of the main root, and at concentrations of 6 percent to 8 percent, the surplus sugar is then diverted primarily to storage root formation. These concepts were deduced from the results of earlier experiments involving light intensity, day length, day temperature, and night temperature (11).

The present report concerns the studies that were made to determine whether or not beets develop in the manner indicated and the extent to which the "ripening" processes are controlled by self-regulatory mechanisms within the plant and by reactions of the plant to the external environment. If sugar beet plants "ripen" (or rather "sugar up") when grown with ample supplies of water and nutrients at natural day lengths under controlled temperatures in a greenhouse, it would indicate that "ripening" is associated with an internal growth pattern, or with changes in day length, light intensity, or light quality. If, however, the plants fail to "sugar up," then "ripening" could very well be related to day and night temperature, mineral nutrition, or to a combination of temperature and nutritional changes,

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[2] Numbers in parentheses refer to literature cited.

or to factors as yet unknown. None of the plants in the present experiment flowered, indicating that without a low temperature induction period, the changes in day length or in quality of sunlight at Pasadena, California, from January 20, 1951, to August 26, 1952, were without effect on flowering.

Procedure

Sugar beet seed of the variety US 22/3 treated with Phygon XL (one gram per 100 grams of seed) was planted in vermiculite (Number 2 grade) on January 20, 1951, at the rate of 10 seed balls per pot and at a depth of ¾ inch. The tins, 10 inches wide and 12 inches deep, were painted on the inside with a nontoxic plastic material (Amercoat No. 33). Drainage was provided for by means of four holes at the bottom of each pot. Modified Hoagland's culture solution was added immediately after planting and at daily intervals thereafter. A total of 48 trucks, with 4 pots to a truck, were used in the experiment. These were kept for natural day lengths in a greenhouse maintained at 23° C. from 8 a.m. to 4 p.m. and at 17° C. from 4 p.m. to 8 a.m. The seedlings emerged on January 25, 1951. On February 7, 1951, when the plants were at the late two-leaf stage, they were thinned to one plant per seed ball. On February 20, 1951, at the four-leaf stage, the plants were thinned to four plants per pot; on February 26, to two plants per pot; and finally on March 6, 1951, to one plant per pot. In the final thinnings the very small and the very large plants were removed in order to obtain a uniform stand. During the growth period from January 20, 1951, to August 26, 1952, the trucks (20 inches x 20 inches) were rerandomized every week in order to minimize the effects of position on plant variability. Also, at weekly intervals the old leaves were removed, counted, dried, and saved for inclusion in the total dry weight of the tops of each plant. The plants from two trucks selected at random were harvested at each harvest period. Each plant was separated as follows: (a) living blades more than 1 inch wide; (b) blades of recently matured leaves; (c) petioles of recently matured leaves; (d) unclassified material (petioles, immature leaves, and tip of the crown); and (e) beet storage roots. The tops were separated from the roots by cutting the plants at the junction of the green and old leaves. After this separation, the beet roots or crowns were trimmed, regardless of size, by trimming lightly as recommended for large beets in commercial tare laboratories. This procedure tended to include more crown material of the small beets than commercially practiced, but had the advantage of placing the beets of all sizes on the same basis. When the crowns became large, separate analyses for sucrose were made on the crown and storage root. These values are reported separately in Table 2 and as weighted

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Figure 1.—Growth and development of sugar beet plants in a controlled temperature greenhouse from the seedling stage to the age of three years. Growth for the first two months was confined primarily to tops and to fibrous roots. Top growth increased to three months and shortly thereafter remained relatively constant. Storage root development began slowly at the age of two months, increased in rate at three months and thereafter proceeded at a rapid pace for 5 to 6 months. Crown growth began at six months and thereafter constituted most of the growth of the storage tissues. No storage root growth took place after the first year. At all times new leaves developed, matured, aged, and died.

averages in Tables 1 and 3 (starting with the values for August 21, 1951). Pulp samples weighing 26.0 grams each were sealed separately in glass jars and frozen immediately by means of dry ice. Duplicate samples were analyzed for sucrose content, using a saccharimeter and the hot extraction method as outlined by Browne and Zerban (4).

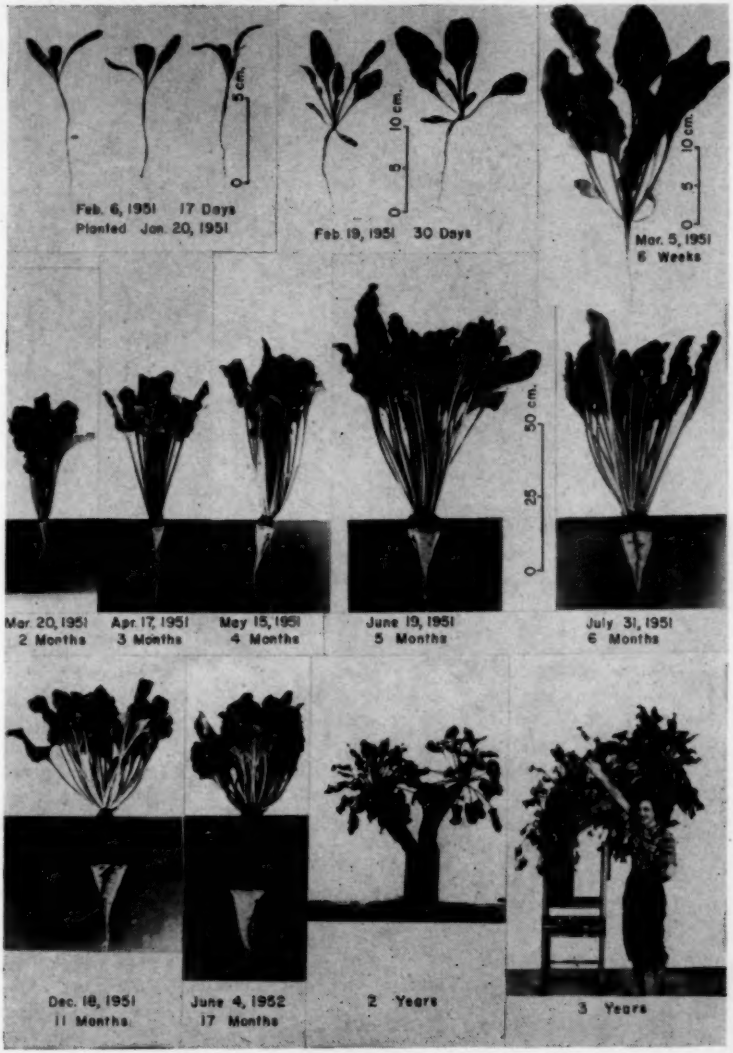

Figure 1.

The vermiculite in the pots of the low-nitrogen series was washed nearly free of nitrate with tap water on July 31, 1951. The beets in this series were watered daily thereafter with a minus nitrogen culture solution until the plants were harvested. The culture solution without added nitrogen was the same as the complete solution, except that calcium chloride was substituted for calcium nitrate and potassium sulfate for potassium nitrate.

The maintenance of specific air temperatures in the Earhart Laboratory greenhouses has been described by F. W. Went (9). Temperature readings that were made of the outgoing air showed that the minor fluctuations in temperature during a 24-hour period averaged close to the assigned temperatures. The light intensity at noon in the greenhouse when measured normal to the sun by a Weston meter, fluctuated from 1100 to 7000 foot-candles in December to over 10,000 foot-candles in mid-summer. The photoperiods in natural day length were 10.0 hours in December and 14.4 hours in June.

The results of the experiments were analyzed statistically according to the methods of analysis of variance (6).

RESULTS FOR BEETS HIGH IN NUTRIENTS

The results for each harvest date starting on March 20, 1951, when the plants were 8 weeks old, to the last harvest date, August 26, 1952, (age 83 weeks), are given in Table 1. Statistical analyses for all harvest dates were made on the combined data for the actual figures obtained or on values transformed to logarithms which then gave error variances that were relatively constant for each harvest date (6). The results of these analyses served as a guide to drawing a line through a series of points, particularly for the plateau of the curve. Growth patterns of the beet plants, with respect to time, were followed photographically (Figure 1) and by plotting the average values for the top weight, the sucrose concentrations of the storage roots, and the weights of the storage roots (Figure 2).

Top Growth

The fresh weights of the tops are given in Table 1 and in Figure 2. The growth curve of the tops takes the familiar S-shape pattern in which growth is rather slow initially and then increases rapidly, reaching a plateau in May, June, July, and August. Thereafter, the decreases are only slight, even though the days in the winter months are only 10 hours long and the light intensities are much less than those of summer months. Apparently, top growth has priority over the rest of the plant for sucrose utilization, except for basic metabolism. This contrasts sharply with the lack of storage root growth and the losses in sucrose content of the beet root during the winter months (Figure 2). Maintenance of top growth at the expense of storage root formation and the sucrose content of the roots also may be seen in the dry weight of the tops (exclusive of old dead leaves) and in the fresh and dry weights of the blades of living leaves (Table 1). Old leaf formation is at a steady rate, which means that if the fresh weight of the tops and the number of living leaves is to remain relatively constant during fall and winter months (Table 1), new leaf growth must be taking place continuously. If photosynthetic activity of the plants had become still less in winter, top growth would have suffered also, and of course, in continuous darkness the tops would have died.

Sucrose Concentration

The sucrose concentration of the beet roots increased from 4.6 percent on March 20, 1951, to a maximum value of 9.3 percent on July 31, 1951, and then decreased slowly to 6.6 percent on December 18, and finally to 3.9 percent on March 11, 1952. After that, the maximum values for 1952 failed to reach those for 1951. In 1951, the increases in sucrose concentration of the beet roots roughly paralleled the increases in top growth, both attaining plateau values toward the end of May, 1951. A further examination of the sucrose concentrations of storage roots and crowns (stem tissue) for

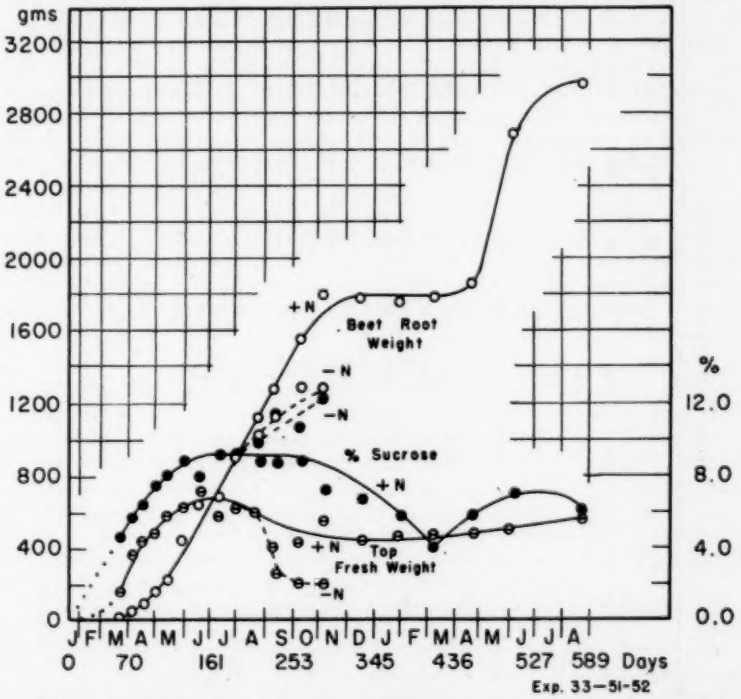

Figure 2.—Influence of time and nitrogen upon the beet root weight, sucrose concentration and the fresh weight of tops of sugar beet plants. The plants were grown with ample supplies of water and nutrients for natural day lengths in a greenhouse kept at 23° C. from 8 a.m. to 4 p.m. and at 17° C. from 4 p.m. to 8 a.m. During a period of 83 weeks the plants high in nutrients (solid lines, +N) failed to "ripen" or to "sugar up." "Ripening," however, was induced by watering comparable plants with a nitrogen free culture solution starting July 31, 1951 (broken lines, —N). The maximum sucrose concentration of these plants (12.1 percent on November 6, 1951) compares favorably with the maximum value of 9.3 percent of plants high in nitrogen (July 31, 1951), but this value is still far short of the sucrose concentrations of beets grown commercially. Beet roots (roots + crown) failed to increase in weight during the winter months.

Table 1.—Results for Beets High in Nutrients.

Harvest dates	Age days	Beet root Fresh weight gm.	log	%	Sucrose gm.	log	Tops Fresh weight gm.	Tops Dry weight gm.	Old leaves Dry weight gm.	log	Living blades Number	Living blades Fresh weight gm.	Living blades Dry weight gm.	Petiole NO_3-N p.p.m.
Mar. 20, 1951	59	21	1.30	4.6	1.0	—0.04	155	10.4	0.5	—0.34	15.8	71	5.8	32,100
Apr. 3, 1951	73	51	1.68	5.7	2.9	0.44	364	24.4	1.6	0.19	21.8	135	11.6	31,900
Apr. 17, 1951	87	102	1.96	6.4	6.5	0.77	423	28.0	6.7	0.79	23.9	138	12.8	29,900
May 1, 1951	101	163	2.14	7.3	11.6	0.99	548	38.9	14.2	1.12	27.3	166	16.5	28,900
May 15, 1951	115	237	2.36	8.0	19.1	1.26	582	44.8	20.8	1.29	31.1	206	17.9	27,600
May 29, 1951	129	455	2.61	8.7	39.7	1.55	623	54.0	25.8	1.39	38.0	188	20.5	25,200
June 19, 1951	150	645	2.79	8.0	52.7	1.69	714	57.1	47.0	1.66	35.8	213	21.8	27,000
July 10, 1951	171	675	2.72	9.2	62.8	1.68	575	43.0	54.1	1.71	37.5	154	16.7	25,700
July 31, 1951	192	907	2.92	9.3	85.2	1.89	618	55.0	73.9	1.84	50.4	161	19.1	26,300
Aug. 21, 1951	213	1,134	3.01	8.7	96.9	1.94	585	50.8	95.0	1.95	39.1	177	19.9	24,100
Sept. 11, 1951	234	1,277	3.08	8.6	108.3	2.01	408	35.9	126.4	2.09	31.0	118	14.8	25,800
Oct. 9, 1951	262	1,562	3.15	8.6	135.6	2.08	417	36.6	128.9	2.09	41.0	131	15.4	23,100
Nov. 6, 1951	290	1,813	3.24	7.1	129.2	2.08	545	46.6	149.9	2.15	42.4	155	18.1	35,000
Dec. 18, 1951	332	1,786	3.20	6.6	121.3	2.01	440	37.0	159.8	2.15	42.6	141	16.0	25,800
Jan. 29, 1952	374	1,774	3.22	5.7	104.5	1.96	474	47.3	180.0	2.23	42.0	159	19.5	23,900
Mar. 11, 1952	416	1,789	3.20	3.9	69.5	1.77	467	42.9	241.1	2.36	41.5	151	19.0	31,600
Apr. 22, 1952	458	1,871	3.22	5.8	121.0	1.92	495	50.8	256.5	2.39	49.6	162	22.4	18,800
June 4, 1952	501	2,696	3.41	6.7	176.9	2.22	493	52.1	266.9	2.40	49.5	154	22.5	17,400
Aug. 26, 1952	584	2,977	3.46	5.8	172.5	2.19	558	59.4	355.8	2.52	43.1	146	20.9	20,100
Significant difference[1]		.....	0.21	1.3	.....	0.25	192	18.4	.....	0.16	7.6	63	6.4	5,000
Significant difference[2]		.....	0.28	1.8	.....	0.33	254	24.3	.....	0.21	10.0	83	8.5	6,600
F-Value[3]		16.9	67.7	11.0	12.2	50.4	5.13	3.53	27.5	188.8	12.7	1.96	3.31	6.85

[1] At the 5% level.
[2] At the 1% level.
[3] Required F-value at the 5% level is 1.68, at the 1% level, 2.07.

late 1951 and for 1952 is informative (Table 2). At first, the sucrose concentration of the storage root proper was higher than the crown, but beginning with the December 1951 harvest, the crowns had a significantly higher sucrose concentration than the storage roots. This is important if there is to be a consistent explanation of storage root growth in relation to beet root sucrose concentration. The sucrose concentration near the growing point thus appears to determine the rate of storage root and crown development.

Storage Root Growth

The average beet root weight for each harvest is given in Table 1 and in Figure 2. Increases in storage root size were relatively small until the top growth of the beet plant and the sucrose concentration of the storage root were nearly at their maximum values (Figure 2). Thereafter, the increase in beet root size was nearly linear until the fall and winter months of 1951 when the shorter days and lower light intensities resulted in a lower root sucrose concentration and slightly smaller top growth. During the winter period, beet root size (root plus crown) failed to change, and it was only in Spring 1952 that the beet root weight (mainly crown) increased (Table 2). Apparently it was only then that a surplus of sucrose was available for crown growth. At this time, the total root plus crown weight increased sharply, but the rate of increase again decreased upon the approach of Fall with its shorter days and lower light intensities.

Sucrose Stored

The average amount of sucrose stored in the roots at each harvest is given in Table 1. Increases in the amount of sucrose stored in the beet roots were at first extremely small, and then by May 1951, the increases were larger and stayed at a constant rate of increase until September 1951. After that, there was no change in the amount of sucrose stored until January 1952, when the amount stored decreased significantly. In March, the amount of sucrose stored declined to a minimum value which was followed by a sharp increase and by a period of no change in July and August 1952.

Table 2.—Weights and Sucrose Concentrations of Roots and Crowns of Beet Plants High in Nutrients.

Harvest dates	Fresh weight of Root	Fresh weight of Crown	Observed F-value[1]	Sucrose Root	Sucrose Crown	Observed F-value[1]
	gm.	gm.		%	%	
Aug. 21, 1951	514	607	0.8	9.18	8.15	56.8
Sept. 11, 1951	609	667	1.3	9.10	8.14	22.3
Oct. 9, 1951	739	811	1.7	9.04	8.15	10.6
Nov. 6, 1951	732	1,057	15.6	6.80	7.26	0.8
Dec. 18, 1951	868	908	0.1	6.43	6.83	5.9
Jan. 29, 1952	740	1,007	29.6	4.76	6.36	9.6
Mar. 11, 1952	590	1,188	10.4	2.48	4.51	32.5
Apr. 22, 1952	590	1,270	14.7	4.52	6.34	13.0
June 4, 1952	745	1,917	40.4	4.59	7.67	37.0
Aug. 26, 1952	793	2,147	34.4	4.04	6.59	28.6

[1] Required F-values at the 5% and 1% levels are 5.6 and 12.3 respectively.

Petiole Nitrate

Petiole nitrate was determined on the recently matured leaves of the beet plants (10). The results of these analyses are given on the dry basis as means of six plants instead of the eight plants for the other values in Table 1. The nitrate values for the plants high in nutrients are far from being deficient during the growth study. A statistical analysis of these values (Table 1) indicates that a difference of 6,600 p.p.m. is necessary at the 1 percent level for significance between any two means. Even though many of the differences observed during the course of the experiment are significant, their physiological significance is not known.

RESULTS FOR SUGAR BEETS LOW IN NITROGEN

The sugar beet plants low in nitrogen were grown in Hoagland's culture solution until July 31, 1951, when the nitrate of the nutrient solution was replaced by chloride and sulfate. Three weeks later, on August 21, the first set of plants was harvested. These were compared with the plants supplied with nitrogen and harvested at the same time.

Top Growth

There was very little difference in the appearance of the leaves, the fresh weight of the tops or the weight of the beet roots for the plants in the two nitrogen treatments on August 21 (Table 3 and Figure 2). The petiole nitrate-nitrogen of the high nitrogen plants was 24,100 p.p.m. and the low nitrogen plants 11,700 p.p.m. The latter value, while significantly lower than for the high nitrogen plants, was still considerably above the critical concentration and accordingly, no decrease in growth would be expected (10). The higher sucrose concentration of the beet roots and the lower weight of the living blades, while in the right direction, were not significant statistically.

On the second harvest date, September 11, 1951, the effects of nitrogen deficiency on top growth were pronounced. The fresh weight of the tops of the deficient plants was somewhat more than one-half of those receiving nitrogen. The number of living leaves did not change significantly between the two treatments, thus indicating that the size of the leaf blades had decreased greatly for the nitrogen deficient plants. The outer leaves of the low nitrogen plants had turned yellow and the petioles of recently matured leaves used for analysis were found to be extremely low in nitrate.

On October 9 and November 6, there were no further decreases in the top growth of the nitrogen deficient plants, as shown by the fresh and dry weights of the tops and living blades. The number of leaves formed by the nitrogen deficient plants was again the same as those grown in complete culture solution. The old leaves from the nitrogen deficient plants, during the period from July 31 to November 6, weighed somewhat less than those of plants in complete culture solution. This is considered to be the outcome of the slower growth of the nitrogen deficient plants.

Storage Root Growth

On August 21, the storage roots of the nitrogen deficient plants were somewhat smaller than those of non-deficient plants (Table 3 and Figure 2). After that, the differences in root size became greater, with the greatest

Table 3.—Results for Beets in the Low and High Nitrogen Treatments.

Harvest dates	N level	Age days	Beet root: Fresh weight gm.	Beet root: Sucrose %	Beet root: Sucrose gm.	Tops: Fresh weight gm.	Tops: Dry weight gm.	Old leaves Dry weight gm.	Living blades: Number	Living blades: Fresh weight gm.	Living blades: Dry weight gm.	Petiole NO_3-N (dry basis): p.p.m.	Petiole NO_3-N (dry basis): log
Aug. 21, 1951	+N	213	1,134	8.7	96.9	585	50.8	95.0	39.1	177	19.9	24,100	4.38
Aug. 21, 1951	—N	213	1,021	9.7	98.6	586	55.6	96.9	42.4	153	17.8	10,500	4.00
Sept. 11, 1951	+N	234	1,277	8.6	108.3	408	35.9	126.4	31.0	118	14.8	25,800	4.41
Sept. 11, 1951	—N	234	1,131	11.2	127.2	246	23.0	113.9	28.8	66	8.4	1,870	3.04
Oct. 9, 1951	+N	262	1,562	8.6	135.6	417	36.6	128.9	41.0	131	15.4	23,100	4.34
Oct. 9, 1951	—N	262	1,290	10.5	136.4	203	21.4	115.5	40.0	65	8.7	340	2.48
Nov. 6, 1951	+N	290	1,813	7.1	129.2	545	46.6	149.9	42.4	155	18.1	35,000	4.55
Nov. 6, 1951	—N	290	1,280	12.1	152.7	189	21.8	134.1	43.9	69	9.4	430	2.47
Significant difference, 5% level		.....	n.s.	1.2	n.s.	140	13.3	4.0	8.3	40	4.5	.....	0.29
Significant difference, 1% level		.....	n.s.	1.6	n.s.	186	17.7	5.3	11.1	53	6.0	.....	0.39
F-Value[1]		.....	1.79	15.5	1.15	11.6	8.5	1.75	3.6	10.4	8.34	73.1	76.1

[1] Required F-value at the 5% level is 2.18, at the 1% level, 2.84. n.s. = not significant.

Table 4.—F-values and Error Variances of Beet Plants in Relation to Time and Nitrogen Nutrition.

Source of variation	DF	Required F-values: 5%	Required F-values: 1%	Observed F-values: Beet root: Fresh weight gm.	Beet root: Sucrose %	Beet root: Sucrose gm.	Tops: Fresh weight gm.	Tops: Dry weight gm.	Old Leaves Dry wt. gm.	Living blades: Number	Living blades: Fresh weight gm.	Living blades: Dry weight gm.	Petiole NO_3-N p.p.m. as logs
Treatments	7	2.18	2.84	1.79	15.47	1.15	11.57	8.5	1.75	3.61	10.4	8.3	76.1
Nitrogen level (N)	(1)	4.01	7.10	3.81	80.09	0.73	27.43	13.2	1.00	0.04	33.4	27.9	382.3
Harvest date (D)	(3)	2.77	4.14	2.42	0.91	2.23	13.38	11.9	3.60	8.06	11.4	8.6	23.0
N x D	(3)	2.77	4.14	0.49	8.47	0.20	4.47	3.5	0.16	0.35	1.73	1.5	27.1
Error variance	56	.....	.....	296.574	1.38	2.756	19,507	175	1,584	69.41	1,555	20.4	0.063

difference being observed on November 6, the last date of harvest for the plants of the low nitrogen series. However, none of the observed differences in root growth were significant statistically, even though the treatment effects were highly significant for other measurements made upon the plants (Table 3 and 4).

Sucrose Content

The sucrose concentration of the low nitrogen beets (Table 3 and Figure 2) followed the pattern that has been observed many times in nitrogen deficient plants. On August 21, the sucrose concentration of the low nitrogen beets was one percentage unit higher than the comparable beets watered with culture solution containing nitrogen. On September 11, the difference was 2.6 percentage units, on October 9, 1.9 percentage units, and on November 6, 5.0 percentage units. The difference of 5.0 percentage units on November 6 was brought about by an increase in sucrose concentration of the nitrogen deficient beets and, at the same time, by a decrease in sucrose concentration of the beets fertilized with nitrogen. The F-values (Table 4) for the nitrogen effect and the interaction of nitrogen and time were highly significant even though the main effect of time was not. Of interest, too, is the fact that, at no time, was the sucrose percentage of the low nitrogen beets (Table 3) as high as that of field grown beets, namely, from 16 to 20 percent. The reason for the low sucrose concentration of laboratory beets is still being investigated, but recent results indicate that a combination of low night temperature and a low nitrogen content of the beets is conducive to high sucrose concentrations, especially during growth periods with long days.

Sucrose Stored

The amount of sucrose stored in the beet roots low in nitrogen was, as a rule, greater than in beets high in nitrogen (Table 3). However, these increases were not significant statistically. Apparently, the higher sucrose concentrations of the beets low in nitrogen did not make up the loss in their beet root weight and the net effect of the nitrogen deficiency was no real change in sugar stored by the beets.

Petiole Nitrate

The nitrate-nitrogen values for the petioles taken from the beet plants correspond to the nitrogen treatments (Table 3). What was not expected was the relatively slow rate at which the plants growing in vermiculite and watered with a solution lacking nitrogen, became low enough in nitrate to decrease growth. On August 21, the low nitrogen plants still had 11,700 p.p.m. of nitrate-nitrogen in the petioles, which is much higher than the critical concentration at which a decrease in growth might be expected (10). On September 11, when the average values were near the critical concentration, top growth had decreased greatly, and the size of the beet roots had decreased somewhat. On October 9 and November 6, the petiole nitrate values were well below the critical nitrate-nitrogen concentration, and this was strongly reflected in the smaller leaves and beet roots. At the same time, the sucrose concentration of the beet roots had increased sharply, a phenomenon which has been observed may times in plants deficient in nitrogen.

Discussion

The results of the present experiments indicate that sugar beet plants have no internal mechanism for "ripening" or "sugaring up" when the plants are grown in a controlled temperature environment highly favorable to beet growth. Under the same conditions as those in which the beet plants were grown, a tomato seed will germinate, develop leaves, and form flowers. The flowers will set fruit which ripen to form tasty tomato fruit. In contrast to the tomato, sugar beet seeds will also germinate, form cotyledonous leaves, and then develop regular vegetative leaves in rapid succession. The new vegetative leaves as they are formed will reach a maximum size and number in accordance with the genetic composition of the variety and the climate (temperature, light intensity, and day length) in which the plant is growing. The leaves will become mature, grow old, and gradually die, but this is as far as development proceeds as long as the climate remains constant (Figure 2). If, however, the environment is changed by lowering day temperatures to 17° C. and nights to 12° C. and the day lengths kept at 12 to 14 hours, the sucrose content of the beet root will increase from values of 8 to 10 percent to a value of 12 percent (unpublished results of this laboratory). This value is still quite low in comparison to the 16 to 20 percent of commercially grown beets. Flowering of some varieties, such as US 22/3, will also take place at these temperatures. At higher temperatures in the greenhouse, the sucrose concentrations become still lower at the day lengths normal to Pasadena, California.

During the early period of growth of the sugar beet plant, the sucrose concentration of the beet root increases slowly and then gradually reaches a maximum value of 8 to 10 percent. This occurs about the time of maximum top development (Figure 2 and Table 1). Thereafter, the sucrose concentration of the storage root remains relatively constant over a wide range of light intensities and day lengths (11). The reason for the relative stability of the sucrose concentration of the beet root appears to be that when there is more sugar formed by the beet plant than needed for maintaining top and root growth, the extra sugar is not used to increase the sucrose concentration of the storage root nor to form more and larger leaves, as one might expect, but mainly to increase the size of the storage root (Figure 2).

The rate of increase in beet root weight appears to be constant for a constant environment. In the controlled temperature greenhouse, the rate of root formation is high during the summer months and, thereafter, the rate falls to a low or zero value in the late fall and winter months (Figure 2). Apparently, during the short days of the winter months, the sugar formed is not enough to increase the beet root weight or even to maintain top growth at maximum values. The decrease in fresh weight of the tops during the winter is also accompanied by a decrease in the sucrose concentration of the beet roots, which is another indication that the sugar formed in winter is not sufficient to meet the demands made for sugar by the plant.

The temperatures of the greenhouse during the fall and winter months were higher than those of the outdoors. If the beets had been kept in the

greenhouse at lower temperatures, then their tops would have failed to grow, and most likely the sucrose concentration of the roots would not have decreased. Thus, in growing beets in the field during the winter for spring harvesting, the outcome of the crop will depend upon the amount of sunlight the crop receives and the temperatures of the days and nights. If days are too short and temperatures too high, the sucrose concentration of the beets will decrease as observed in the experiments in the Earhart Laboratory. However, if the temperatures are too low for growth, beet roots will not increase in size, and only if harvesting is delayed until late spring or early summer, will there be a major increase in beet root (crown) weight. Once the plants start growing again in the spring, the rate of increase, it is to be noted, is much greater than when the plants are started from seed (Figure 2). Counteracting this advantage of rapid growth during the second year will be the tendency of some varieties to form seed stalks after having been subjected to a cold winter. If cold resistant varieties can be developed to overcome this reproductive habit, then overwintered beets should produce much more sugar than the beets that are started from seed.

The size of tops formed by beet plants is perhaps a good measure of the amount of sugar that the plant can form. Thus, varieties with large tops should produce more sugar than small topped varieties. What is not indicated by top size alone is the use made of the sugar after it is formed by the plant. The conversion of large amounts of sugar to top and root growth would result in a storage root with a low sucrose concentration. A smaller conversion of sugar to tops and storage roots would give roots with a higher sucrose concentration. This is what takes place in nitrogen deficient plants; the tops become smaller, the storage roots fail to increase in size, and at the same time, the roots increase considerably in sucrose concentration.

This inverse relationship between the nitrogen status of the plant and the sucrose concentration of the beet root has been observed many times (11) and has led to the suggestion that beets should be harvested when they have become deficient in nitrogen. This precaution in the use of nitrogen could be disregarded if a variety could be found that is high in sucrose even though the plant is high in nitrogen. Such a variety, if it is to be acceptable commercially, should produce large tops and fibrous roots early in its life cycle, and thereafter, the sugar produced should be distributed within the plant in such a manner that the storage root is always high in sucrose regardless of its nitrogen status. Under these conditions, the losses in sugar production that often occur from nitrogen deficiencies or from nitrogen excesses would be avoided, and instead, the sugar produced would be proportional to the time the beets are left in the field.

Summary

Sugar beet plants high in nutrients were grown with ample supplies of water and nutrients in vermiculite in a controlled temperature greenhouse (23° C., 8 a.m. to 4 p.m.; 17° C., 4 p.m. to 8 a.m.) for natural day lengths from January 20, 1951, to August 26, 1952. Starting July 31, 1951, part of the plants of this series were made deficient in nitrogen by watering with a culture solution lacking nitrogen. At frequent intervals the beet

roots of representative plants of each set were weighed and analyzed for sucrose content. The tops and all separations thereof were weighed fresh and again when dried. Petioles of recently "matured" leaves were analyzed for nitrate content. All data were analyzed statistically.

The plants of the high nutrient series failed to "sugar up" or "ripen" during the 83-week period of growth. This indicates that sugar beet plants have no internal mechanism for "ripening" such as the one found in the tomato plant. Also, the results indicate that the changes in day length, light intensity, or light quality normal to Pasadena do not cause "sugaring up" as long as the plants are kept at 23° C. during the day and at 17° C. during the night, and the plants are well supplied with nutrients and water. This suggests that "sugaring up" as found in the field must be associated with decreases in temperatures during the day or night, nutrient deficiencies, or to factors not now known.

As the sugar beet plants grew, the growth of fibrous roots and of tops took precedence over the growth and the accumulation of sucrose in the storage root. As the tops increased in size, the sucrose concentration in the storage root also increased. At the time of maximum top growth a maximum sucrose concentration, characteristic of the climate (temperature, day length, and light intensity) and beet variety (genetic composition) was attained. At this time, storage root growth proceeded at a rate directly proportional to the sucrose formed in excess of requirements for top growth, fibrous root development, and basic metabolism. When there was no surplus of sugar during the winter months, storage root growth ceased, sucrose concentration of the root decreased, while at the same time, top growth declined only slightly.

The storage root proper of the beet plants high in nutrients increased in size until late September. Thereafter, growth of the "beet root" was confined primarily to the crown or stem tissue of the plant. The sucrose concentration of the storage root was higher at first than that of the crown, but beginning in December, the crown was higher than the storage root.

When the plants of the low nitrogen series became deficient in nitrogen, beet root growth decreased, top growth declined, and the petiole nitrate values fell below the critical concentration. During this time, the sucrose concentration of the storage root of deficient beets increased to 12.1 percent, and the non-deficient beets declined to 7.1 percent. The value of 12.1 percent for the nitrogen deficient beets was still low in comparison to the 16 to 20 percent of most field grown beets.

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Physiology of Growth, Sugar Accumulation and Mineral Intake of Sugar Beets in Montana

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The purpose of the investigation was to determine criteria which would indicate malnutrition of sugar beets during their early development. Beets were sampled at 10-day intervals beginning about July 10. Six continuous plots of sugar beets treated as follows were sampled: Check (no treatment), phosphorus, manure, nitrogen, manure and phosphorus, and manure, phosphorus, and nitrogen.

Beets emerging about May 1 should have tops and crowns averaging about one-half pound by mid-July and one pound by mid-August in order to have a satisfactory commercial yield of roots. The roots should weigh about .7 pound by mid-August.

Petiole analyses showed that at least 1000 p.p.m. of nitrate nitrogen should be maintained throughout August. Phosphate concentration in the petioles of the higher yielding plots was about 1500 p.p.m. throughout the season. Soil tests showed that available phosphorus was very deficient in the check and nitrogen plots and sufficient in the other four plots. Seedling diseases and fusarium yellows showed a negative correlation with the fertility of the plots.

The percentages of sugar as determined before mid-August, showed a negative correlation with the final yield.

The results of this study show that in order to produce a commercially profitable crop of sugar beets, the fertilization program should be flexible taking into consideration the potential productivity of the soil and the environmental conditions under which beets are grown. Growth measurements, petiole and soil analyses should be made the basis for the nutritional requirements of sugar beets.

(Note—The detailed data of this study have been submitted for publication, Bulletin 491, Montana Experiment Station, In Press.)

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Effect of Quantity of Mineral Nutrients on Germination and Seedling Growth of Sugar Beets[1]

F. W. SNYDER[2]

Although the vital role of mineral nutrients in the growth of plants has been known for a number of decades, investigations concerning the quantity and balance of nutrients required for maximum crop production still remain fruitful.

The striking effects of drought or disease during germination and emergence of field crops are widely recognized. On the other hand, the influence of nutritional factors on germination and emergence may escape detection. Mineral nutrient reserves in a seed are limited. As a result, growth of the young plant may be retarded by the dwindling supply of nutrients in the seed, especially when this supply cannot be supplemented adequately by absorption from the growing medium.

Experiments have been conducted in the greenhouse to determine the effect of quantity and balance of mineral nutrients upon seedling emergence and growth of some sugar beet varieties.

Methods and Results

Builders sand, in six- or seven-inch pots, was used. Nutrient solutions were prepared with tap water, the composition being given in Table 1.

The first experiment was designed to test the effect of concentration of nutrients on early growth. Ten processed seedballs of variety US 215 x 216 (produced in California in 1951) were planted in each pot. Nutrient solution number one (Table 1) was applied daily, beginning the first day after planting (100 milliliters per pot per day). Table 2 is a summary of the emergence and vigor of the seedlings maintained on different nutrient levels. The differences between the numbers of seedlings which emerged in the four treatments were not statistically significant. The small percentage of tall seedlings in the tap water treatment only four days after emergence of the first seedlings, indicates a very limited mineral nutrient reserve in the sugar beet seed. Seedlings maintained on tap water were significantly smaller than those which received nutrient solution. The reduction in the number of seedlings in the treatment receiving full strength nutrient solution may have been due to the more concentrated solution.

In another experiment, the variation in nutrient balance of the four solutions listed in Table 1 did not cause any statistically significant differences in the emergence of variety SP 53AB3-0. Solution number one was diluted with an equal volume of tap water prior to application to the pots.

A comparison of the emergence behavior of five varieties was made where tap water was applied to one series of pots and 100 milliliters of

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solution number three was applied daily, beginning the first day after planting, to a second series. Four replications were used. Fifteen seedballs were planted in each pot or a total of 60 seedballs per treatment. The emergence data are found in Table 3.

The addition of nutrient solution hastened emergence during the sixth or seventh days for all five varieties as compared with those receiving only tap water. The magnitude of the response appears to be differential and dependent upon the variety. Differential emergence behavior is evident among the varieties, SP 53AB3-0 emerging rapidly and SP 5377-0 emerging rather slowly.

The actual percentage emergence data reveal that 1.7 to 13.3 percent greater emergence occurred where nutrient solution was applied as compared with application of tap water. The average increase was 8.4 percent.

A comparison of seedling development among the five varieties, 20 days after planting, is shown in Table 4. The superiority of SP 53AB3-0 in rapid emergence and development is evident from Tables 3 and 4. While

Table 1.—Composition of Nutrient Solutions.

Salt	Grams of salt per 15 liters of water			
Solution No.	1	2	3	4
$CaCl_2.2H_2O$	.....	.....	.....	8.82
$Ca(NO_3)_2.4H_2O$	7.08	14.16	9.23	.....
KH_2PO_4	10.21	10.21	18.37	18.37
$K_2HPO_4.3H_2O$	.....	2.61	2.61	.....
KNO_3	18.10	.....	.....	.....
$MgSO_4.7H_2O$	6.00	6.00	6.00	6.00
NH_4Cl	.....	.....	.....	3.21
$NH_4H_2PO_4$	.....	.....	.....	1.73
NH_4NO_3	1.20	.....	.....	.....
$CuSO_4.5H_2O$	0.04	0.04	0.04	0.04
$FeSO_4.7H_2O$	0.19	0.19	0.19	0.19
H_3BO_3	0.01	0.01	0.01	0.01
$MnSO_4.H_2O$	0.05	0.05	0.05	0.05
$(NH_4)_6Mo_7O_{24}.4H_2O$	0.08	0.08	0.08	0.08
$ZnSO_4.7H_2O$	0.05	0.05	0.05	0.05
Characteristics of sol'n:				
pH	6.61	6.40	6.30	6.19
Approx. ratio of N-P-K-Ca				
Full strength	9-2.5-8.5-1	4-3-3-2	2.5-4.9-4.9-1.5	2.5-5-4.5-2
Half strength	4.5-1.2-4.2-0.5			
Form of nitrogen	Nitrate and Ammonium	Nitrate	Nitrate	Ammonium

Table 2.—Effect of Concentration of Mineral Nutrient Solution on Emergence and Vigor of Seedlings of Sugar Beet Variety US 215 x 216.

Solution	Percent germination of seedballs 7 days	No. of seedlings per pot* 7 days	9 days	Size distribution of seedlings 7 days after planting, expressed as percent Tall	Intermediate	Short
Tap water	50	7.5	9.5	4.4	31.1	64.5
¼ strength	60	10.3	10.7	61.3	17.7	21.0
½ strength	70	11.5	11.5	75.4	11.6	13.0
Full strength	65	9.7	9.8	75.8	17.3	6.9

* Averages of six replications.

these varietal differences undoubtedly exist, it is not known whether the magnitude of differences would remain unaltered if seeds harvested in the same year and from the same location had been used for this experiment. The seeds of SP 53AB3-0 and SP 5377-0 were harvested in 1953 at different locations. The other varieties were harvested one to three years earlier and not all from the same location.

Discussion

From these experiments, there is evidence of a very limited reserve of available mineral nutrients in the seed during germination and emergence. In addition, emergence from sand was more rapid where mineral nutrients were applied than where only tap water was applied. Also, approximately eight percent more emergence occurred where nutrient solution was applied to the sand as compared to application of tap water. These observations indicate that a low level of soil fertility may contribute directly to poorer stands, as well as slower growth of the sugar beet seedlings.

Table 3.—Comparison of Emergence of Five Varietes of Sugar Beets.

Variety	Treatment	Cumulative percent emergence for indicated days after planting[1] 5 AM	6 AM	6 PM	7 AM	7 PM	8	9	15	20	Actual percent of seedballs emerged[2]
SP 53AB3-0	Tap water	1.8	13.0	24.1	66.7	74.1	77.8	81.5	98.1	100.	90.0
	Nutrient Sol'n	1.7	21.7	40.0	70.0	76.7	85.0	90.0	98.3	100.	100.0
US 400	Tap water	—	—	4.1	22.4	36.7	61.2	79.6	98.0	100.	81.7
	Nutrient Sol'n	—	1.8	18.5	53.7	63.0	75.9	85.2	98.1	100.	90.0
Mich. H-134	Tap water	—	2.0	5.9	23.5	43.1	68.6	76.5	98.0	100.	85.0
	Nutrient Sol'n	—	1.9	7.7	38.5	50.0	57.7	69.2	98.1	100.	86.7
SP Acc 1178	Tap water	—	—	—	3.0	6.1	21.2	63.6	90.9	100.	55.0
	Nutrient Sol'n	—	2.4	4.9	7.3	14.6	31.7	63.4	90.2	100.	68.3
SP 5377-0	Tap water	—	—	5.6	16.7	16.7	22.2	50.0	100.0	100.	30.0
	Nutrient Sol'n	—	4.3	8.7	13.0	17.4	26.1	39.1	100.0	100.	38.3

[1] Based on total number of seedballs from which emergence of seedlings was noted 20 days after planting.
[2] Based on total number of seedballs planted.

Table 4.—Distribution of Seedlings of Five Varieties of Sugar Beets Among Size Classes After 20 Days Growth on Tap Water or Mineral Nutrient Solution.

Variety	Treatment	Percent of seedlings by size classes[1] Most developed	Next	Intermediate	Small
SP 53AB3-0	Tap water	5.2	5.2	38.6	51.0
	Nutrient Sol'n	40.4	26.0	24.0	9.6
US 400	Tap water	1.0	4.9	19.8	74.3
	Nutrient Sol'n	32.7	12.4	40.7	14.2
Mich. H-134	Tap water	2.7	0.9	27.0	69.4
	Nutrient Sol'n	10.2	16.1	46.6	27.1
SP Acc 1178	Tap water	0.0	5.5	47.9	46.6
	Nutrient Sol'n	8.6	13.4	64.6	13.4
SP 5377-0	Tap water	5.6	0.0	61.1	33.3
	Nutrient Sol'n	4.5	18.2	50.0	27.3

[1] Based on size of the two primary leaves. Due to non-uniform shape of these leaves, standards were chosen for each class. These could not be delineated into absolute size units.

The marked differential behavior in rate of emergence and development among varieties, as well as within a given variety, points to the desirability of selecting progeny for rapid emergence and development as a possible means of increasing acre yields.

Summary

Experiments, using builders sand and mineral nutrient solution or tap water, were conducted to study emergence and seedling growth of five varieties of sugar beets. Emergence behavior and seedling growth indicate a very limited reserve of available mineral nutrients in the sugar beet seed. Comparison of emergence, where either tap water or mineral nutrient solution was applied, revealed that more rapid emergence and a slightly greater percentage emergence occurred where mineral nutrient solution was applied. Varietal differences in rate of emergence were noted.

The Relation of Soil Water Levels to Mineral Nutrition of Sugar Beets[1]

OMER J. KELLEY AND JAY L. HADDOCK[2]

General Relationships

Several reviews have recently been made on studies of mineral accumulation in plants and factors which affect it (2, 3, 29)[3]. There is general agreement that the two main groups of influences which determine the extent and rate of solute absorption are the external or the environmental conditions and the internal or controlling physiological conditions. The more important external conditions are temperature, aeration, supply of water and amount and type of mineral salts. The more important internal controlling conditions are the hereditary characteristics of the particular plant, its previous physiological history and the supply of stored carbohydrates which is available for respiratory activity of the roots. While these various factors are all important and in many cases are interrelated, we will consider primarily water and its role in nutrient uptake. Mineral nutrition is related both directly and indirectly to soil moisture.

Surface Migration and Ion Diffusion

The literature indicates plants may obtain nutrients directly by contact exchange or from solution. In any event, the nutrients are usually thought to be taken up in a dissociated form and, therefore, water is necessary, whether or not the ions must actually undergo surface migration or pass through a moisture film.

The importance of surface migration or diffusional movement of ions for nutrient absorption by plants was well illustrated by Wadleigh.[4] He refered to an experiment by Dittmer (7) who studied the development of a rye plant on a dark loamy soil. The plants were grown for four months in wooden containers 12x12x22 inches or approximately 1.8 cubic feet. Dittmer made a very careful and detailed study of all of the roots at the end of the growing season. His records showed the plant had approximately 13,800,000 roots with a length of more than 6,600 miles and a surface area of around 4,321 square feet. All of these roots were in approximately 1.8 cubic feet of soil. Certainly one would be justified in considering a root system that exposed more than 6,870 square feet of surface in less than 2 cubic feet of soil as "thoroughly permeating" that soil.

Let us now consider the ratio of the exposed root system area to the specific surface of such a loamy soil as used by Dittmer. Such a soil might have a specific surface of around 20 square feet per cubic centimeter or a total of about 900,000 square feet for the soil in the container. All of the root surface is not in contact with the soil surface, since the soil is not a

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[1] The experimental results reported herein were obtained from Western Regional Research Project W-9, with eleven Western States, B.P.I. S.&A.E., S.C.S. (Research) cooperating. Project Leaders: J. L. Haddock, V. Hansen, S. Taylor.

[2] Head, Western Section of Soil and Water Management, Soil and Water Conservation Research Branch, U.S.D.A., Beltsville, Maryland, and Soil Scientist of the same Section and Branch, U.S.D.A., Utah Agricultural Experiment Station, Logan, Utah, respectively.

[3] Numbers in parentheses refer to literature cited.

[4] Talk before American Society of Agronomy, Cincinnati, 1952—unpublished data.

solid mass but is interspersed with pores. It can be shown that in the case of Dittmer's culture, less than 1 percent of the soil surface was in direct contact with the roots. Therefore, if the nutrient ions adsorbed on the surface particles were to enter the root, at least 99 percent of them would either have to undergo surface migration or diffusion through a moisture film.

High Water Table and Dry Soil Conditions

In addition to the role of water indicated above, water may well have an effect on the development of the root system. Normally high water tables may confine the roots close to the surface and reduce the root volume per plant and thus reduce the available nutrient supply. The adverse effect of a high water table or prolonged low soil moisture stress is thought to be due primarily to its effect on oxygen content. As the soil moisture tension decreases, the soil pores become increasingly filled with water. The amount of gas is thus reduced and the gaseous exchange is inhibited. Furr and Aldrich (9), studying irrigated date palms on a very fine sandy loam, noted that the oxygen content of the soil air decreased from 20 to 5 percent at the 6 inch depth as the moisture tension dropped from around 700 cm. to 15 cm. but it increased rapidly again as the soil moisture tension approached 100 cm. of water. Several investigators (12, 24) have shown the necessity of adequate oxygen for the accumulation of both anions and cations in plant roots. However, Chang and Loomis (4) presented data which indicate that increasing carbon dioxide content of the air in nutrient cultures may be toxic per se to plants.

Hoffer (11) believes that the high accumulation of reduced iron and manganese associated with anaerobic soils may also be toxic per se to the plant roots.

Excess water can have an adverse effect in the leaching of nutrients beyond the root zone (18). This is evident in the case of nitrate. Other ions removed by leaching in considerable amounts are chloride, calcium, magnesium, sulfate, and bicarbonates. On the other hand, dry conditions in soils may reduce the supply of available nutrients. Root growth at moisture contents below the permanent wilting percentage is slow (1). Dry soil severely reduces root extension and thus limits contact with nutrients. While some nutrient adsorption may take place in dry soil (14, 28), it is not adequate for normal growth. This is the case even if the roots at lower depths have sufficient water but not nutrients and the nutrient supply is in the upper dry soil.

There is a certain amount of limited evidence (5) which indicates that the soil solution is a necessary and integral part of phosphorus absorption by plants. Hunter and Kelley (13) indicated that phosphate ions are not absorbed from dry soils. Volk (28) concluded that cations, but not anions, may be absorbed from dry soils. This is further substantiated by the "contact exchange theory" which has been proposed by Jenny and coworkers (16, 17). They showed that with certain clay or soil suspensions containing Na^+, K^+, or Rb^+, the rates of absorption of ions by barley roots were greater than from corresponding salt solutions. Evidence of a corresponding influence of clay particles on anion absorption is not available. Work by Dean and Rubins (6) failed to show a greater phosphorus absorption in the presence of clay suspensions containing fixed phosphorus.

Boron availability is closely related to soil-water relationships since it is the belief that boron is available to plants only in water-soluble form. Olson and Parks (19, 20) have shown a decrease in water-soluble boron by drying. Walker et al. (30) observed that boron deficiencies were more severe in places in the field where soil dried out excessively in dry years. While dry soil conditions may make boron less available for the immediate plant growth, it is doubtful if drying of the plow layer under field conditions is sufficient to cause appreciable boron fixation. Schofield and Wilcox (25) found sufficient boron in irrigation water in southern California to cause injury to citrus and walnuts. Similar toxic effects of excess boron in irrigation water are found in many areas of the West.

It is apparent that too much or too little water may alter the effective root zone and thus the nutrient supply. Fluctuations in the moisture level may have an effect on the availability of the nutrients in the soil. For instance, fixation of potassium or ammonium in a form unavailable to plants may be accelerated by alternate wetting and drying of soils.

Within the Available Moisture Range

A recent review of the relation of soil water to plant growth has been given by Richards and Wadleigh (23). This review indicates that a number of growth factors are affected by variations in the soil moisture condition within the available moisture range. The question immediately arises as to the effect of variation in the available soil moisture range on nutrient uptake, in addition to its effect on the availability for plant growth. Reitemeier (22) studied the effect of moisture content on the ionic concentrations extracted from various soils. He found an increase in the nitrate and chloride concentration as the moisture content decreased. In general, he found a decrease in concentration of cations and polyvalent anions as the moisture content decreased. Several investigators have found a relationship between moisture content and the apparent absorption of minerals in plants (8, 15, 26). They found plant foliage low in nitrogen and high in phosphorus with high average soil moisture contents. Janes (15) found that calcium, magnesium and sodium decreased in plants with increasing soil moisture. It appears, therefore, that a relationship exists between the availability of the nutrients in the soil water and the moisture tension or content within the available moisture range.

Experimental Results with Sugar Beets[5]

In order to study the effect of soil moisture condition on the nutrient uptake by plants, the authors have selected plant material grown under a variety of irrigation regimes on Millville loam soil at Logan, Utah. The Ulrich method (27) was selected to study the nutritional status of plants as affected by irrigation regime. This procedure attempts to measure the concentration of nutrients moving in the conductive tissue of plants. It has proven to be a sensitive measure of variation in plant environmental conditions.

There were eight irrigation regimes in this study—two methods of irrigation (sprinkler and furrow) and four soil moisture conditions under each method. A description of irrigation treatments is given in Table 1.

[5] The experimental data reported herein were obtained from Regional Research Project W-9 at the Utah Agricultural Experiment Station, Logan, Utah.

Table 1.—Irrigation Treatment and Accompanying Soil Moisture Conditions.

Irrigation Method and Inches Water Entering Soil	Soil Moisture Condition	Soil Moisture Condition Symbol	Soil Moisture Condition at the 12" Depth Before Irrigation
1F[1] and 1S[2] 18.1" 16.2"	Low Moisture High Tension	(W_1)	Allowed to Approach Wilting Percentage.
2F and 2S 20.0" 17.1"	Medium-Low Moisture	(W_2)	About 25 percent of Available Soil Moisture Remaining.
3F and 3S 24.0" 17.6"	Medium-High Moisture	(W_3)	About 75 percent of Available Soil Moisture Remaining.
4F and 4S 33.8" 24"	High Moisture (Low Tension)	(W_4)	Maintain at about Field Capacity.

[1] F refers to furrow irrigation.
[2] S refers to sprinkler irrigation.

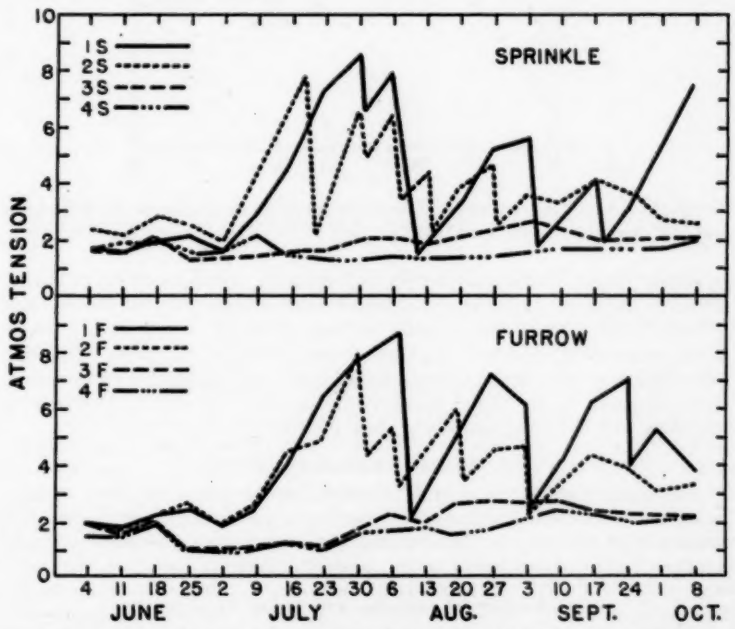

Figure 1.—Variations in seasonal soil moisture tension at 12-inch depth under two irrigation methods and four soil moisture conditions. (Sugar beets 1952.)

A graphical representation of the soil moisture conditions present for each of these irrigation regimes is shown in Figure 1. It will be noted that there was some variation in the soil moisture tensions for a given moisture

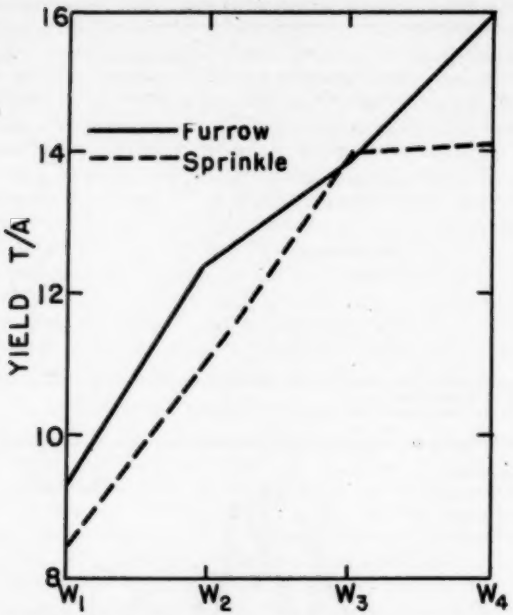

Figure 2.—Yield of sugar beets as affected by methods of irrigation and soil moisture condition. 1952.

treatment between the two irrigation methods. However, there is considerable similarity between the seasonal tension record of the furrow and sprinkle plots. This graph should be kept in mind as reference is made to the nutritional condition of plants grown on the several plots. Although soil moisture conditions were maintained at the approximate moisture level, there appeared to be a greater difference between W2 and W3 relative to the other soil moisture conditions than intended.

Soil Moisture Condition and Yield

Although yield is not of special concern to this discussion, it is of interest to note the effect of soil moisture condition on yield of sugar beets. It is obvious from the data in Figure 2 that yields are highly correlated with soil moisture condition regardless of the method of irrigation.

Soil Moisture Condition and Sugar Percentage

Reference is made to sugar percentage at this time because it has been shown repeatedly that sugar percentage is highly correlated with the nitrogen content of both roots and tops of sugar beets. Again, it is obvious from the data of Figure 3 that sugar percentage of the root increases as the quantity of soil moisture is increased. This is true regardless of the method of irrigation. This phenomenon is probably a result of greater utilization of the available nitrogen in producing plant tissue early in the season on

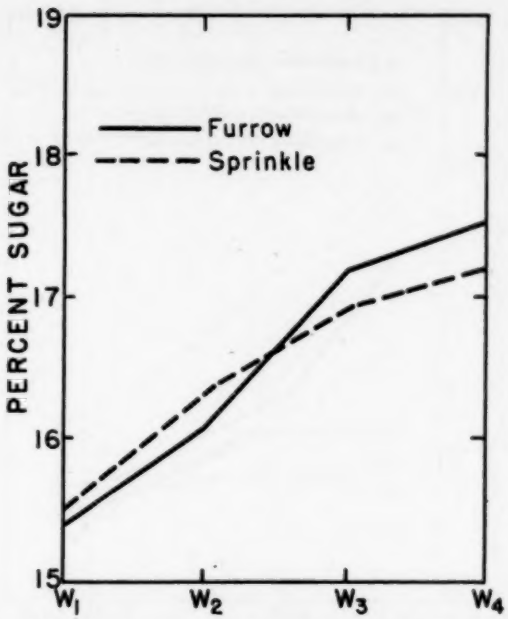

Figure 3.—Sucrose percentage of sugar beets as affected by method of irrigation and soil moisture condition. 1952.

the more moist plots. This in turn encourages greater sugar storage in mature plants. It is possible, also, that the excess water results in downward movement of available nitrogen, beyond the reach of plant roots, as irrigation water in increased.

Soil Moisture, Condition and Phosphorus Uptake

The influence of stage of growth as related to phosphorus uptake and soil moisture condition is shown effectively by the data in Figure 4. The soil moisture condition had a marked influence upon the uptake of phosphorus from soils early in the season. The wetter the soil, the greater the uptake of phosphorus. Late in the season, the phosphorus content of sugar beet petioles is low and relatively independent of soil moisture condition, method of irrigation and fertilization. The season of the year or probably more exactly the stage of plant growth then is an important factor in determining the effect of soil moisture condition on the uptake of phosphorus.

In 1950, three soil moisture conditions were maintained on Millville loam—(1) wet (15 irrigations), (2) medium (5 irrigations), and (3) dry (2 irrigations). Three fertilizer phosphorus conditions were placed on each soil moisture condition—(1) no phosphorus, (2) 100 pounds of P_2O_5 drilled into the surface, and (3) 100 pounds of P_2O_5 placed four inches deep and four inches to the side of the row. The crop was harvested October 21,

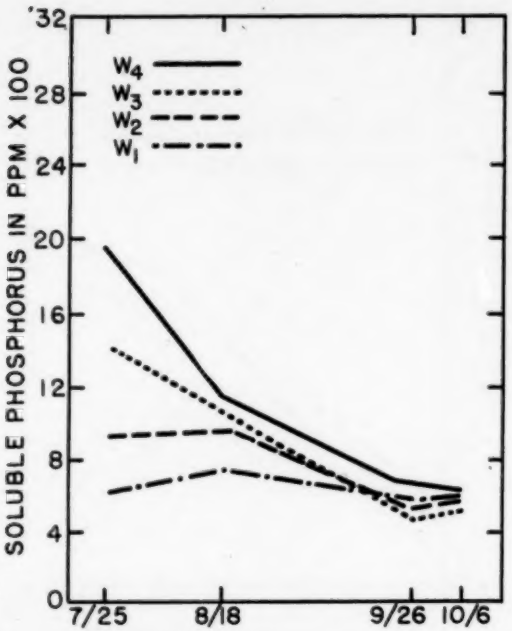

Figure 4.—Seasonal soluble phosphorus content of sugar beet petioles as affected by soil moisture condition. 1952.

yielding 10 to 18 tons per acre. The lowest yields come from the no phosphorus and dry treatment, the highest from 4-inch placement and wet treatment. The whole tops were analyzed for total phosphorus. The data are plotted in Figure 5. It is evident that soil moisture condition is an important factor in the uptake of phosphorus regardless of the method of placement.

Variations in soil moisture had no effect on phosphorus uptake for the plots which received no added phosphorus, and, for the broadcast treatment, were of importance only insofar as a comparison of the medium and dry moisture levels is concerned. The phosphorus uptake of the plants from the medium moisture plots was about 20 percent greater than that for the dry plots. For the 4-inch deep placement, there was an increased uptake of phosphorus with increased moisture throughout the range of moisture studied. The phosphorus content of the sugar beet tops of the wet plots contained nearly 50 percent more phosphorus than those of the dry plots.

Soil Moisture Condition and Nitrogen Uptake

The soluble nitrogen content of sugar beet plants appears to be affected to a greater extent by environmental condition than is the phosphorus.

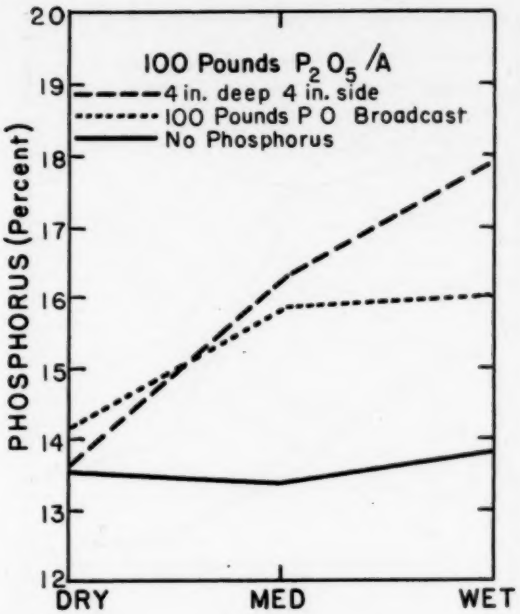

Figure 5.—Phosphorus content of sugar beet tops as affected by soil moisture condition and fertilizer placement. 1950.

There is a marked variation in the soluble nitrogen content of sugar beet petioles as affected by soil moisture condition and method of irrigation.

It is easily seen from the data in Figure 6 that at any given season of the year beet petioles taken from plants growing on dry plots are relatively high on nitrate-nitrogen in contrast to those obtained from wet plots.

Sugar beets grown under sprinkle irrigation generally appear to have a better nitrogen nutritional condition than beets grown under furrow irrigation. Such observations are supported by petiole analyses which indicate that petioles taken from sprinkle irrigated beets on August 18th had a higher nitrogen content. (See Figure 6.) This difference is probably caused by the fact that under furrow irrigation, 30 to 40 percent of total water applied is lost by deep percolation carrying soluble nitrogen materials beyond the reach of the sugar beet plant.

A somewhat similar relationship to that noted above for nitrate nitrogen holds between the soil moisture condition of the soil and the organic-nitrogen content of sugar beet petioles. This relationship is shown in Figure 7. It is interesting to note that if the soil is kept sufficiently dry the soluble organic-nitrogen content of beet petioles does not decrease as the season advances. The amount of the decrease appears to be somewhat pro-

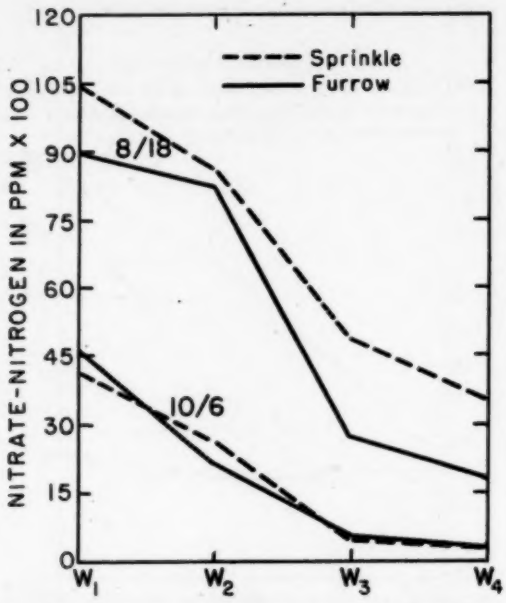

Figure 6.—Nitrate-nitrogen in sugar beet petioles as affected by method of irrigation, soil moisture condition and sampling date. 1952.

portional to irrigation water used (see Table 1). This is in contrast to the nitrate-nitrogen content of sugar beet petioles which drop precipitously late in the season, regardless of soil moisture conditions.

Discussion

The observations noted above on the interrelationships between soil moisture condition, method of irrigation and nutritional status of sugar beet plants are of practical as well as academic interest.

It is generally assumed that when plants are growing in a soil there is a continuous process of nutrient absorption by plants accompanied by a concomitant release of soil nutrients from an insoluble or unavailable to a soluble or available form. It was observed by Pierre and Parker (21) that phosphorus may exist in the soluble form only to the extent of one to three pounds per acre in fairly fertile soils. In order for plants to obtain sufficient phosphorus for their total seasonal requirements, it is estimated that the process of re-solution must be repeated 25 to 30 times in the course of a season. It appears that the amount of available soil moisture present in a soil at any given time determines, to a considerable extent, the amount of phosphorus which can be in solution at that time and, hence, the total amount which is immediately available to plants. The rate at which insoluble soil phosphorus becomes soluble in different soils may be an important factor modifying the relationships observed on Millville loam between

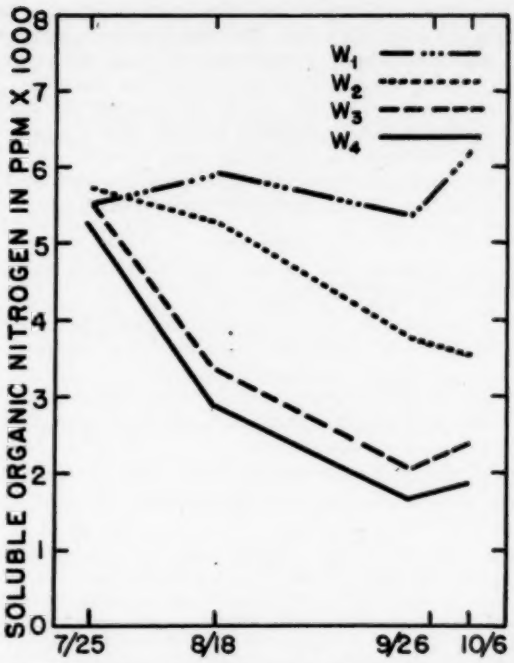

Figure 7.—Seasonal variation in organic nitrogen content of sugar beet petioles as affected by soil moisture condition under furrow irrigation.

available soil moisture and phosphorus uptake by plants. The solubility of soil phosphorus is so low that even with large quantities or irrigation water, little is carried from the soil with water lost by deep percolation.

Since the quantity of soil water available to plants is closely related to the quantity of available phosphorus, it is frequently difficult to know whether plant growth is dominated by soil moisture tension or by the availability of phosphorus.

The effect of soil moisture condition on the uptake of phosphorus is in marked contrast of its effect on nitrogen uptake. Although nitrate-nitrogen is probably not the only form of nitrogen which sugar beets absorb from the soil solution, nitrogen is absorbed largely in this form. Apparently nitrification can proceed at relatively low soil moisture conditions. Plants growing in relatively dry soil show a high nitrogen concentration in their tissues, as compared to plants growing on moist soils. This may result from the fact that when any water percolates through a soil it may carry with it large quantities of nitrate-nitrogen which may be taken beyond the reach of plant roots. Soil nitrates are highly soluble while soil phosphorus compounds are only slightly soluble. On the other hand, it may be that when plants are grown on dry soils, the rate of growth is slowed by high soil moisture tension, allowing nitrates to accumulate in plant tissue.

Factors favoring the accumulation of the plant nutrients nitrogen and phosphorus are in sharp contrast. The soil moisture condition which is favorable to high phosphorus accumulation is, as a rule, unfavorable to high nitrogen accumulation. This may mean that when all plant nutrients are considered, there will be found a narrow soil moisture condition which is best suited to the development of high yield and good quality in crops. It has been shown elsewhere (10) that for both yield and quality of roots in sugar beets, the optimum quantity of available nitrogen is norrowly limited, but this can be modified considerably by irrigation practice.

Summary

In summary, therefore, we can state that water is important in nutrient uptake of plants in the following ways.

1. It is the medium through which nutrients must pass to be taken from the surface of the root into the inner vacuole.

2. Too much water may have an adverse effect insofar as root accumulation of nutrients is concerned in the following ways:

   A. Limiting root growth by low oxygen concentrations or development of toxic substance.

   B. Leaching of nutrients below root zone.

3. Too little water affects the concentration of nutrients in soil and their availability to plants.

4. There appears to be a relation between nutrient uptake and variations of moisture content between field capacity and wilting percentage. In sugar beets ,the phosphorus content is increased with increasing soil moisture content, while the nitrogen content is decreased and is affected to a greater extent than phosphorus.

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The Need of Basic Research in Phosphate Fertilization Problems of Sugar Beets

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Many practical problems related to the phosphate fertilization of sugar beets have been answered reasonably well as a result of field, greenhouse, and laboratory experiments. Few basic relationships have been discovered, however, which are applicable to all soils. Usually the results obtained in one field experiment have a limited application for predicting fertilizer response on a different soil. Repetition of the usual field experiment is not providing the answers for the solution of this problem. There still exists a primary concern to develop a suitable method to measure plant available phosphorus in the soil applicable to a wide range of conditions.

Soils are known to react in various ways with fertilizer phosphate to change its availability to plants. The nature of the soil properties which cause these differences and some of the properties of the forms of phosphorus resulting from these interactions have been studied extensively (2, 3, 5, 7, 11)[2] but the evaluation of these soil properties in terms of observed differences in fertilizer response is very limited. With newly developed methods for measuring plant available phosphorus and the nature of the reaction products of the fertilizer phosphorus with the soil, however, it would appear that more thorough studies can now be made relating soil properties to fertilizer response. In addition, more information is needed on the effect of environment (1), the relative properties of soil and root surfaces as they affect the relationships of yield to phosphorus uptake and supply, and the differences between crops in relation to their need and absorbing capacity for phosphorus.

This paper reviews a few studies which have contributed toward the solution of these problems and points out some lines of approach which appear most promising.

Nature of Reaction Products of Fertilizer Phosphate with Soil

The purpose of this section is to emphasize the known properties of these reaction products and to show how the information may be applied to fertilizer problems. Specific properties of the various forms of phosphorus are not known in detail, nor is there a sharp distinction between them, but their over-all contribution in supplying phosphorus to the soil solution is the most important factor to measure.

More complete discussions of the various forms of soil phosphorus have been described previously (3, 5, 7, 10, 11, 12). In general, the fertilizer phosphate reacts with the soil in two different ways to form (a) a fairly reactive fraction of high availability, and (b) an inactive fraction of low availability. The reactive fraction is probably dissolved fertilizer phosphate, phosphate on the surface of soil particles and finely divided phosphate precipitates, which readily exchanges with anions in the soil solution, and

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[2] Numbers in parentheses refer to literature cited.

phosphate held in the double layer surrounding clay particles. The inactive fraction is the phosphate bound inside precipitates formed from ions in the soil solution, and phosphate bound on the surfaces of clay minerals, hydrous iron and aluminum oxides. The fraction exchanges very slowly with radiophosphate ions in the soil solution.

The relationship between the effectiveness of a phosphate fertilizer and the manner in which it reacts with the soil involves two important considerations, i.e. (a) the rate of conversion to the active and inactive fractions, and (b) the relative amounts of each fraction which may be formed. Assuming a water-soluble type fertilizer such as concentrated superphosphate, the rate of conversion to the active fractions, for that portion of the phosphate which diffuses away from the fertilizer particle to contact the soil, is probably complete within a few hours. The secondary reactions converting the active fraction to the inactive fraction proceed slowly and with varying intensity in different soils. The evidence indicates that these secondary reactions require several months or more for completion (6, 9, 13). The rate of these secondary reactions is increased by increasing temperature, soil moisture, clay content, number of wetting and drying cycles and by a decrease in pH or exchangeable calcium.

The relative amounts of the active and inactive fractions formed change with time and cropping (10, 13). Initially, the reaction products appear to exist as minute pockets of phosphate-rich soil, their availability decreasing slowly over 3 to 4 months. After cultivation, cropping, biological transformations, wetting and drying, and plowing, these phosphate-rich pockets become more thoroughly mixed with the soil and less available to plants.

As a result of these various reactions, the fertilizer phosphorus is held by the soil with varying bonding energies. The rate of renewal and capacity to replenish the soil solution phosphorus will depend upon the relative amounts of the active and inactive fractions present, their solubility, and surface area. The availability to plants of the soil solution phosphorus depends also upon the nature and surface area of the roots, the competition of other anions in the soil solution for adsorbing sites on the root surface, competition by microorganisms, metabolic processes in the plants, soluble salts, pH, and others.

A practical objective in making use of the above information is the development of methods to measure plant available phosphorus and more rapid chemical methods which satisfactorily estimate the available phosphorus. This problem is difficult to solve in view of the complexity of factors involved. If predictions of fertilizer response can be made with 85 to 90 percent accuracy, such methods have great practical value in fertilizer usage.

Measurements of Plant Available Phosphorus

"A" value—A measurement of plant available phosphorus more rapid than field tests has long been needed as a standard by which to judge the reliability of plant and soil analyses. Such a measurement can be obtained through the use of radioactive phosphorus in greenhouse pot tests (4). The available soil phosphorus is measured in relation to the available phosphorus from a phosphate fertilizer, usually concentrated superphosphate. The effect

of the subsoil is not determined, although this factor may be quite important on some soils. If a survey were needed of the phosphate fertility status of a large number of soils, or the residual effect of applied phosphate fertilizers or soil management practices, a measurement of "A" values would probably provide the most reliable index.

The relationship of "A" values to yield response in the field and the greenhouse is shown in Table 1. These samples were described previously (8), but one additional modification was used for the data in Table 1. If the yield of the check plot was less than 50 percent of the fertilized plot in the greenhouse experiment, the soil was considered likely to respond to phosphate applications in the field. Fifteen soils fell in this category and a significant response in the field experiment was not observed, possibly as a result of other limiting growth factors.

Table 1.—Yield Response in Field and Greenhouse in Relation to "A" Values. (90 Locations.)

"A" value lbs. P_2O_5/A	No. responding	No. not responding	Percent responding
0-60	9	0	100
61-120	32	1	97
121-180	6	9	40
181-240	0	15	0
over 240	0	18	0

Surface phosphorus—A measurement of "A" value may not be feasible in all cases. More rapid determinations of available phosphorus closely related to "A" values are obtained through the use of radio-phosphorus in the laboratory based on essentially the same principles as the "A" value measurement (7). The surface phosphorus represents that portion of the various forms of phosphorus in the soil which will readily exchange with radiophosphorus in the soil solution, or the portion of the solid phase phosphorus in near equilibrium with the solution phosphorus. No dissolving action on the various forms of phosphorus is involved in this measurement. Approximately 30 to 50 percent of the residual phosphorus which accumulated in calcareous or neutral soils occurs as surface phosphorus (7).

$NaHCO_3$—soluble phosphorus—The amount of soil phosphorus soluble in 0.5 molar solutions of $NaHCO_3$ at pH 8.5 has been shown to be highly correlated with "A" values and yield response for a wide variety of soils (8). This method should prove useful in making surveys of the phosphate fertility status of a wide range of soil types, as well as provide reliable information useful in making fertilizer recommendations.

The relationship of $NaHCO_3$—soluble phosphorus to yield response in field and greenhouse experiments is shown in Table 2. The soils are the same as those described for the relationship with "A" value.

Table 2.—Yield Response in Field and Greenhouse in Relation to $NaHCO_3$—Soluble Phosphorus. (90 Locations.)

$NaHCO_3$-soluble lbs. P_2O_5/A	No. responding	No. not responding	Percent responding
0-25	19	0	100
26-50	27	6	82
51-75	0	15	0
over 75	1	24	4

Recommendations for Future Studies on Phosphate Fertility Problems of Sugar Beets

This section is meant to be a guide only, with emphasis placed on the application of newly developed methods to soil management and fertilizer usage problems directly related to phosphate fertility.

A major problem is to develop an accurate soil test to estimate available phosphorus for sugar beets. Such a test will indicate the need for phosphate on a given field. It should reflect the contribution of residual phosphate from fertilizers and manure and the approximate rate of renewal of the soil solution phosphate so that subsequent needs for the following crops can be estimated. This test would not be intended to show crop differences in need of phosphate, so the levels of soluble phosphate indicating a low or adequate supply of available phosphate may be different depending on the crop grown. The contribution of the subsoil to the available phosphate would not be measured by the test.

Differences in soluble phosphate between soils as affected by the energy with which the phosphate is held by the soil due to chemical combinations with iron, aluminum, and calcium should be measured by the soil test, but differences in solubility of the phosphate as a result of soil texture may need adjustment by employing different levels of soluble phosphate in relation to texture. For example, a clay loam and a sandy loam may contain the same amount of available phosphorus, but the clay soil will release less phosphorus to the extracting solution because of its higher adsorption capacity for phosphate. The clay loam, however, may contain twice as much soil solution as the sandy loam. The relationship between texture and level of soluble phosphate indicating low or adequate supplies needs further study.

Final calibration of the soil test should be made with soils from sugar beet fields of known phosphate response. The field experiment should be carefully conducted and observed to note if any growth factors limit yields in addition to available phosphate levels.

If the soil test performs as indicated in the above conditions with corrections for soil texture and crop requirement, high correlations between soluble phosphate and yield response would likely be found. Other factors affect the available phosphorus supply, however, to modify this relationship. These factors are (a) the supply of inorganic phosphorus released from biological transformations of organic phosphorus, and from the action on the soil phosphorus of the microorganisms themselves or their decomposition products, and of the plant roots, (b) the effect of other anions, such as hydroxide, silicate, bicarbonate, nitrate, and soluble salts, in the soil solution on the rate of phosphate absorption by the root, (c) environmental factors of temperature, rainfall, etc., and (d) the effect of soil structure, moisture supply, soil depth, and aeration on the development of roots in the soil.

Some of these factors such as (b) above may be studied in the greenhouse and available phosphorus measured by the "A" value technique. The effect of (a) is difficult to assess, but for practical purposes may be

considered to be essentially similar for soils with similar organic matter contents and soil temperatures, and for a given crop. Field experiments are necessary to evaluate the effects of (c) and (d). For a given soil and season, these factors would be evaluated by the yield response relationship to soluble phosphate. If these factors cause large effects between different soils, then the number of field experiments required would depend on the soil variation encountered. When methods are worked out to evaluate these factors, then the number of field experiments necessary for accurate calibrations can be decreased.

The measurement of surface phosphorus referred to previously appears to be the best laboratory method at present for estimating the available phosphorus in soils. The "A" value measurement is longer but more accurate since plants are employed to measure phosphorus uptake. A close approximation of either the "A" value or the surface phosphate is provided by the $NaHCO_3$ extraction method. It is believed that the application of these methods should facilitate the solution of some of the phosphate fertility problems in sugar beets.

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Effect of Method of Application on the Availability of Phosphate for Sugar Beets[1]

W. R. Schmehl, Sterling R. Olsen, and Robert Gardner[2]

The results of experiments conducted with sugar beets in Colorado (4, 6)[3] have shown that phosphate fertilizer applied with a rotiller was more available early in the season than band-placed fertilizer, whereas, the two methods of application were equally efficient by midsummer and early September. Good response to phosphate, when plowed under, for sugar beets has been reported in Colorado (3, 6). To further evaluate phosphate materials, studies have been conducted at this Station to determine interactions between phosphate materials and method of application. The results reported here summarize the effects of method of application of phosphate fertilizers on phosphorus uptake and yield of sugar beets.

Materials and Methods

1950 Experiment

The experiment was conducted on Las Animas clay soil located on an American Crystal Sugar Company farm near Rocky Ford, Colorado. The soil contained approximately 7 percent $CaCO_3$ and 0.2 percent gypsum in the surface 8 inches. The sodium bicarbonate available phosphorus (5) was 44 pounds P_2O_5 per acre.

Concentrated superphosphate, ammonium phosphate, and liquid phosphoric acid were each applied at the rate of 80 pounds P_2O_5 per acre. Nitrogen was applied to give a uniform rate of 60 pounds per acre. The superphosphate was applied at planting: 1. in a band about 4 inches deep and 4 inches to the side of the seed, and 2. with a rotiller which mixed the fertilizer with the soil in a band 4 inches deep and 4 inches wide and in which the seed was planted. The ammonium phosphate was applied by the same methods used for the concentrated superphosphate and also in about one-half inch of irrigation water. The phosphoric acid was applied in about one-half inch of irrigation water. The fertilizer added in irrigation water was mixed with water in 10-gallon milk cans and applied to the furrow through a garden hose to 10-foot sections of alternate 22-inch beet rows. The beets were planted April 4 and the liquid fertilizers were added April 6. The entire experimental area was row-irrigated April 7 to promote germination.

Radioactive phosphorus fertilizer[4] was applied to a small area in each plot. Plant petiole samples, taken on May 22, June 19, August 1, and September 11, were analyzed for radioactive phosphorus according to methods described by MacKenzie and Dean (1, 2).

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[3] Numbers in parentheses refer to literature cited.

[4] The radioactive phosphate fertilizers, except phosphoric acid, were prepared by A.R.S., U. S. Department of Agriculture.

1951 Experiment

The experimental area for the 1951 experiment was located on the Agronomy Farm near Fort Collins, Colorado, on Fort Collins loam, a non-saline soil containing about 5.0 percent $CaCO_3$ in the surface 8 inches of soil. The available phosphorus in the soil was 31 pounds P_2O_5 per acre (5).

Superphosphate fertilizer was applied at two rates, 50 and 250 pounds P_2O_5 per acre, and by two methods of application. The methods of application were: 1. at planting in a band about 4 inches deep and 4 inches to the side of the seed, and 2. broadcast and plowed down about 2 weeks before planting. Ammonium nitrate was added to give a uniform rate of 184 pounds nitrogen for all treatments. Radioactive phosphate was applied to a small area in each plot at the 50-pound P_2O_5 rate. The plants were sampled June 7, July 9, and July 26 for the measurement of radioactive phosphorus.

1952 Experiment

The experiment was conducted on Fort Collins loam soil on the Agronomy Farm. The soil contained about 1.7 percent $CaCO_3$ and 40 pounds available P_2O_5 (5) per acre in the plow layer. Phosphate from various non-radioactive phosphate fertilizer sources was applied at rates of 25 and 100 pounds P_2O_5 per acre. Ammonium nitrate was broadcast uniformly to give a rate of 84 pounds nitrogen per acre. The four methods of phosphate application were: 1. fall plow under—the phosphate was plowed under October 11, 1951; 2. spring plow under—the phosphate was plowed under April 4, 1952; 3. disked into surface two to three inches of soil on April 15, 1952; and 4. combination band and seed placement—for the 25-pound rate, the fertilizer was applied with the seed; for the 100-pound rate 25 pounds P_2O_5 was applied at planting in a band 4 inches to the side and 4 inches below the seed. The experiment was planted April 16, 1952.

A second source of fertilizer phosphorus radioactive superphosphate, was applied at the rate of 40 pounds P_2O_5 in a band to one row of each plot in the experiment. Plant petiole samples taken July 9 and August 13 were analyzed for radioactive phosphorus.

The experiment was severely damaged by a hail on June 28. This de layed the first sampling and also caused reduced yields.

Results and Discussion

Effect of Method of Application on the Uptake of Fertilizer Phosphorus

The percentage of phosphorus in the plant derived from the fertilizer is shown in figure 1 for the 1950 experiment. The band and rotiller placements for the dry fertilizers were averaged because the uptake of phosphorus from superphosphate and ammonium phosphate was generally about the same for each of the dry fertilizer placements. The averages for each method of application of dry material are compared with the phosphorus derived from the ammonium phosphate and phosphoric acid applied in the irrigation water.

There was not a significant difference in phosphorus uptake from the two fertilizers applied in the irrigation water at any sampling date. At the time of the first sampling, the rotiller-placed fertilizer supplied the most fertilizer phosphorus to the crop, the fertilizer applied in the irrigation water

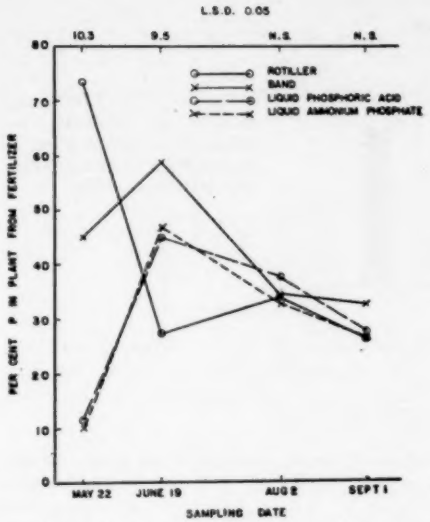

Figure 1.—Effect of placement and phosphate source on percentage of phosphorus derived from the fertilizer. 1950.

supplied the least phosphorus, and the band-placed fertilizer supplied an intermediate amount of phosphorus. About a month later, the band-placed fertilizer was most available, the rotiller-placed fertilizer was least available, and phosphate applied in the irrigation water was intermediate in availability as shown by the phosphate uptake data. At the last two sampling dates, there was not a significant difference in phosphorus uptake from fertilizer applied by the various methods.

Differences in the availability of the fertilizer, as shown by phosphate uptake, were probably caused by differences in soil moisture distribution and the relative positions of phosphate fertilizer and zones of root growth. The greater early uptake of phosphate from the rotiller-placed fertilizer was probably the result of the close proximity of fertilizer and seedling. Phosphate applied in the concentrated band was farther from the roots of the growing seedling and phosphate applied in the irrigation water was still farther from the roots, hence lower early-season availability. The relative availability of the band and liquid-applied phosphates reached a maximum as the season progressed. Reduced phosphate uptake from the rotiller-placed fertilizer after the first sampling was associated with greater depth of root penetration and dry surface soil. During the latter part of the growing season, significant differences between methods of application disappeared.

The uptake of phosphorus from band and plow-under superphosphate in the 1951 experiment is shown in figure 2. The phosphate that was plowed under was much more available at the time of the first sampling, but there was not a significant difference between the two methods of application for the next two samplings. When the fertilizer was plowed under, the phosphate would be distributed at random through the plow layer; thus,

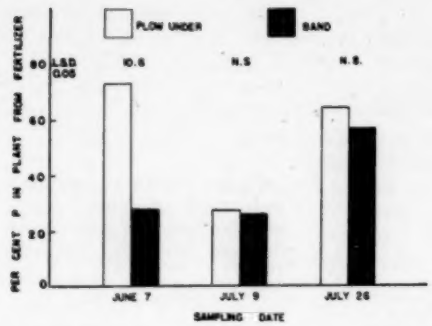

Figure 2. — Effect of method of fertilizer application on percentage of phosphorus derived from the fertilizer. 1951.

there would be a supply of fertilizer phosphorus directly below or near the seed for early season plant growth and deeper placed phosphate for mid-summer and fall growth. The band-placed superphosphate was in a less favorable position for early season availability.

The marked early season effect of method of application on the absorption of fertilizer phosphorus was associated with the corresponding top growth response shown in figure 3. Visual differences in top growth were no longer observed by mid-July.

The results of the 1952 experiments, when expressed as percentage of plant phosphorus derived from the standard radioactive fertilizer source,

Figure 3.—The early season growth of sugar beets as affected by method of application of superphosphate fertilizer. The fertilizer was plowed down in the plot on the right and side dressed in the plot on the left. Both plots received phosphate at the rate of 250 pounds P_2O_5 per acre, 1951.

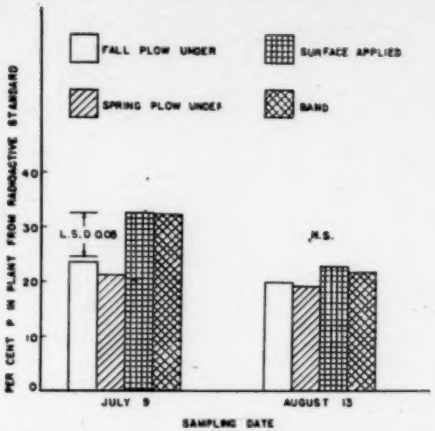

Figure 4.—Effect of method of application of phosphorus on percentage of phosphorus derived from a standard radioactive phosphate source. 1952.

are shown in figure 4. The uptake of phosphorus from the radioactive fertilizer indicates the relative availability of the non-radioactive phosphate; the greater the uptake of phosphorus from the radioactive fertilizer band, the lower the availability of the non-radioactive phosphate. At the first sampling (July 9) the phosphate fertilizer was more available when plowed under than when applied in band or when disked into the surface soil. There was not a significant difference in the availability of the fertilizer between fall and spring plow-down applications, nor was there a significant difference between band and surface applications. By August 13, there was not a significant difference in the availability of the phosphate fertilizer as affected by method of application.

Yield and Sugar Content of Beets

The yields of sugar beets as affected by method of phosphate application are shown in Table 1 for 1950 and in Table 2 for 1951 and 1952. The yields of beets are the result of all factors affecting plant growth, whereas, the data presented in the previous section show the effects of environment only on the uptake of fertilizer phosphorus by the sugar beets. If phosphorus were limiting plant growth throughout the season, then differences in phosphorus uptake should be shown by differences in yield.

In all three experiments there was a highly significant increase in yield as the result of application of phosphate fertilizer. Yields in 1950 show that the effect of method of phosphate application was not significant. The superphosphate and ammonium phosphate fertilizers applied in band or rotiller-placement produced about the same yield as ammonium phosphate or phosphoric acid applied in the irrigation water.

In the 1951 experiment on Fort Collins loam there was not a significant difference in yield between plow-under and band methods of phosphate

Table 1.—Yield and Sugar Content of Beets Grown on Las Animas Clay, 1950.

Treatment	Yield of beets (tons per acre)	Sugar content
		%
Band-placed phosphate*	23.4	15.2
Rotiller-placed phosphate*	22.6	15.0
Ammonium phosphate in irrigation water	22.5	14.8
Phosphoric acid in irrigation water	23.0	15.1
Average—phosphate treatments	22.9**	15.0
No phosphorus	20.0	15.1
L. S. D. phosphate treatments	N.S.	N.S.

* Average for superphosphate and ammonium phosphate fertilizers.
** Highly significant increase compared with no-phosphorus treatment.

Table 2.—Yield and Sugar Content of Beets Grown on Fort Collins Loam, 1951 and 1952.

Method of phosphate application	Yield of beets (tons per acre) 1951	1952	Sugar content % sucrose 1951	1952
Fall plow under	—	14.1	—	15.8
Spring plow under	14.6	14.3	16.9	15.9
Band at planting	14.7	13.3	16.5	16.2
Disked into surface	—	12.9	—	16.0
Average—phosphate treatments	14.7**	13.7**	16.7*	16.0
No phosphorus	11.5	12.0	15.0	15.8
L. S. D. (.05) method of phosphate application	N.S.	1.1	N.S.	N.S.

* Significant increase compared with no-phosphorus treatment.
** Highly significant increase compared with no-phosphorus treatment.

application. In 1952 on the same soil type, the average yield was greater when the phosphate was plowed under as compared with the average for disking into the surface and band application. There was not a significant difference in yield of beets between the fall and spring plow-under phosphate treatments, nor was there a significant difference between the band or surface applications of phosphate fertilizer.

In each of the experiments the method of phosphate application caused early season differences in the amount of phosphorus absorbed by the plant, but by August or early September there were no significant differences in the amount of phosphorus absorbed as affected by method of fertilizer application. The final yield of beets was significantly affected by method of phosphate application only in 1952. The failure to observe a yield response in 1950 and 1951 when large differences in availability of the fertilizer and growth were observed early in the season was contrary to the assumption that a highly available phosphate source is desirable during the early part of the growing season. The fertilizer and soil apparently furnished to the plants a supply of phosphorus which was adequate for maximum crop growth on the least available phosphate treatments. This may have been caused by a combination of too high a phosphate rate and an increased supply of the soil phosphorus as the root system increased. Also, there may have been a limiting growth condition other than phosphorus

in 1950 and 1951 which slowed the growth of the plants receiving the larger amounts of fertilizer phosphorus early in the season. Frequent irrigation and liberal nitrogen fertilization should preclude the possibility of nitrogen and moisture limiting growth in any of the experiments.

The sugar content of the beets at harvest is given in Tables 1 and 2. Only in 1951 was there a significant increase in sugar as the result of phosphate fertilization. There was not a significant difference in the sugar content of the beet as affected by method of phosphate application in any of the experiments.

Summary

The effect of method of application of phosphate fertilizer on phosphate uptake, yield, and sugar content of beets is reported for three field experiments.

In May, the absorption of phosphorus by sugar beets grown in Rocky Ford soil was greater from rotiller-placed phosphate fertilizer than from phosphate applied in the irrigation water or from phosphate placed in bands. In June, the uptake of phosphorus was greatest from band-placed fertilizer. During the latter part of the growing season, phosphorus uptake was about the same from band and rotiller-placed phosphate and from phosphate applied in the irrigation water.

In Fort Collins soil, phosphate fertilizer was more available early in the season when plowed down, than when band or surface-applied, but by mid-summer the uptake of phosphate from the fertilizer was not significantly affected by method of application.

The application of phosphate fertilizer significantly increased beet yields in all experiments. The yields were affected by method of phosphate application only in one of three years.

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The Effect of Fertilizer Applications on Leaf Analysis and Yield of Sugar Beets

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Soil testing is an extremely useful tool; however, not all soil deficiencies can be recognized by soil tests. Further, soil tests cannot be expected to predict the availability of soil nutrients under varying environmental conditions. The most reasonable solution to these problems is to turn to the plant itself. An analysis of the plant will not only reveal all soil deficiencies but it will also enable us to study the effect of environment on nutrient uptake. In addition, plant analysis will furnish specific information about the manner in which varying nutrient levels in the soil affect the uptake and balance of other nutrients in the plant.

Many workers have used the plant analysis approach to soil fertility studies. Ulrich (9)[2] has worked extensively with sugar-beet petioles. He was able to define critical levels of nitrogen, phosphorus, and potassium in the petiole below which it is profitable to apply the fertilizers indicated by the analysis. Haddock (4) has shown that the amount of nitrogen in the soil influences the level of phosphorus found in the leaf and that seasonal changes greatly influence the concentration of nutrients in the petioles. Lagatue and Maume, as quoted by Thomas (8), and later, Thomas himself, used a technique which they termed "foliar diagnosis." This technique examined the effect of fertilizer applications on the quantity and balance of the nutrients in the leaves and the relationship between the quantity and balance of these nutrients and yield. Halais (5) has used foliar diagnosis successfully in diagnosing fertilizer needs of sugar cane. Shear, et al. (6) discussed the importance of considering both the amount and proportions of nutrients present in plant tissue when using plant analysis as a diagnostic tool. Goodall and Gregory (3) have assembled and made a critical evaluation of practically all the research data available up to 1947 concerning the use of the chemical composition of plants as an index of their fertilizer requirements.

After reviewing the literature, a very brief portion of which has been given above, it was felt that sufficient evidence was available to warrant an extensive investigation of the possibility of using leaf analysis to determine the fertilizer needs of the beet crop. The interpretation of the leaf analysis should consider both the amount and balance of nutrients in the leaves. It was decided that analysis of the total amounts of nutrients in the leaves would be more revealing and physiologically sound than any other type of analysis which might be used.

To develop such a plan, it is first necessary to determine how increment additions and combinations of fertilizers applied to the soil influence the yield and sucrose percentage of beets, and how it affects the amount and balance of the nutrients in the leaves. This paper is a report of the effect of fertilizer applications on yield, sucrose percentage, and leaf-nutrient content.

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[2] Numbers in parentheses refer to literature cited.

Methods and Materials

This study was conducted in 1952 on a moderately well-drained Las Animas fine sandy loam. The area selected was in a field of commercially grown beets near Swink, Colorado. All cultural operations necessary for the production of a beet crop were performed by the cooperating grower with the exception of the fertilizer application and the harvesting of the beets. Ten tons per acre of feedlot manure was added to this field, which was in corn the previous year. The field was fall-plowed. The beets were planted April 28 and harvested October 26. The field was irrigated for germination, once in May and once in June, and approximately every ten days thereafter until the last irrigation in late September.

Plots were six rows (twenty-one inches) by thirty feet long with four-foot alleys between replications. The four center rows of each plot were harvested for yield. Two, 15-beet samples per plot were analyzed for sucrose percentage.

Nitrogen, phosphorus, and potassium fertilizers were applied at two levels, zero and some, in all possible combinations in an 8 x 8 latin square field plot design. The treatments were as follows:

1. ck (no fertilizer)
2. n 80 lbs. of nitrogen per acre
3. p 160 lbs. of phosphorus (P_2O_5) per acre
4. k 100 lbs. of potassium (K_2O) per acre
5. np Treatments 2 plus 3
6. nk Treatments 2 plus 4
7. pk Treatments 3 plus 4
8. npk Treatments 2 plus 3 plus 4

The fertilizer sources used were 33.5 percent ammonium nitrate for nitrogen, 43 percent superphosphate for phosphorus, and 60 percent muriate of potash for potassium.

The fertilizer treatments were side dressed eight inches below the bottom of the water furrow, or approximately eleven inches below the soil surface within the row. Water furrows were formed between rows 1 and 2, 3 and 4, 5 and 6 in each plot.

Leaf blade samples were taken three times during the season, on August 13, September 4, and September 26. Morphologically similar leaves were selected on all three dates. At the first sampling, leaves were selected from the first leaf whorl outside the small center leaves. In order that similar leaves could be identified as the leaf whorls were pushed outward by the expanding beet crown, a piece of string was tied to all the petioles in this first whorl on the initial sampling date. At this sampling only every third beet in the center four rows of each plot was sampled. Subsequent sampling was conducted so that one-half of the remaining leaves identified by the string were selected at the second sampling. The remainder of the marked leaves were then sampled at the third sampling.

The samples were placed in a drying oven within 30 minutes after sampling and dried at 80° C. for 72 hours. They were then ground in a Wiley mill, laboratory model, to pass a 20-mesh screen and sealed in half-pint Mason jars. Just prior to analysis the samples were again oven dried for 48 hours at 80° C. to bring all samples to a constant weight.

Leaf samples were analyzed for N, P_2O_5, K_2O, CaO, Na_2O, and MgO and reported as percentage of oven dry weight. Samples were wet ashed by the procedure of Cotton (2), modified for use with hot plates instead of an open flame. This digestion was made to volume and aliquots from it used in all determinations. Nitrogen and phosphorus were analyzed according to Cotton (2), magnesium was determined by the method of Young and Gill (10), while calcium, sodium, and potassium were determined with Beckman DU spectrophotometer equipped with the oxygen acetylene flame attachment. The methods of Brown, et al. (1) were used, primarily, with this flame attachment.

Average weight of beets, percent sucrose, sugar per beet, and the leaf analyses for the three samplings were analyzed statistically by the method of analysis of variance. The significance of the effect of fertilizer treatment on the balance of the six nutrients was also examined by the method of analysis of variance. This balance was examined by forming a ratio of the nutrient under consideration of the sum total of the six nutrients present and multiplying by 100. For example, percent N $\div$ by the sum of the percentages of N, P_2O_5, K_2O, MgO, CaO, and Na_2O x 100 would be the ratio of N to the total amount of nutrients present. This ratio, as a measure of the balance of nutrients in the leaf, was analyzed by the analysis of variance. It is identified throughout the remainder of the report as "percent of total nutrients."

Correlations between leaf analyses values for the six nutrients and average weight of beets, and between leaf analyses and sucrose percentage were computed for the three samplings. Correlations between first sampling leaf analyses values for calcium and phosphorus, phosphorus and magnesium, phosphorus and calcium plus magnesium, and between phosphorus and calcium plus sodium plus magnesium were computed. For the second sampling, the correlation between nitrogen and potassium and between sugar per beet and potassium were computed. Correlations and analyses of variance were computed by the method of Snedecor (8).

Results and Discussion

Table 1-a contains the means of the eight replicate plots for each treatment for the average weight of the beets, the percent sucrose and pounds of sugar per beet (average beet weight multiplied by the percent sucrose). Table 1-b lists the *significant* differences between means due to the seven fertilizer *effects* for the average weight per beet, percent sucrose, and pounds of sugar per beet. Note that fertilizer *treatments* are indicated by lower case letters, while fertilizer *effects* are indicated by capital letters.

At this point, a brief discussion of the fertilizer *main* effects N, P, and K, and the fertilizer *interaction* effects NP, NK, PK, and NPK will simplify later remarks. N represents the *sum* of the effect of nitrogen acting alone, with phosphorus, with potassium, and with both phosphorus and potassium. P represents the *sum* of the effect of phosphorus acting alone, with nitrogen, with potassium, and with both nitrogen and potassium. K represents the *sum* of the effect of potassium acting alone, with nitrogen with phosphorus, and with both nitrogen and phosphorus. NP is the interaction of nitrogen and phosphorus. It is the *sum* of the effect of nitrogen acting with phosphorus

Table 1-a.—Average Weight Per Beet, Percent Sucrose, and Sugar Per Beet by Fertilizer Treatment.[1]

	Treatments							
	ck	n	p	k	np	nk	pk	npk
Avg. Wt. per Beet[2]	1.01	1.23	1.28	1.20	1.21	1.21	1.15	1.34
Percent sucrose	12.5	12.0	12.9	12.3	12.2	11.8	12.6	12.5
Sugar per Beet[2]	.126	.147	.164	.149	.149	.142	.146	.166

[1] Average of 8 plots.
[2] Weight in pounds.

Table 1-b.—Significant Differences Between Sums of Four Means Due to Fertilizer Effects, for Average Weight Per Beet, Percent Sucrose, and Sugar Per Beet.

	Main Effects			Interaction Effects				L.S.D.[2]	
	N	P	K	NP	NK	PK	NPK	5%	1%
Avg. Wt. per Beet[1]	NS[3]	NS	NS	NS	NS	NS	.48*	.48	.64
Percent sucrose	—1.8*	NS	NS	NS	NS	NS	NS	1.56	2.12
Sugar per Beet[1]	NS	.0612*	NS	NS	NS	NS	.0632*	.0596	.0788

[1] Weight in pounds.
[2] L.S.D.: Least difference required for significance.
[3] NS Non-significant difference.
* Significant at 5% level.

and the effect of nitrogen acting with phosphorus but in the presence of potassium. NK is the interaction of nitrogen acting with potassium. It is the *sum* of the effect of nitrogen acting with potassium and the effect of nitrogen acting with potassium but in the presence of phosphorus. PK is the interaction of phosphorus and potassium. It is the sum of the effect of phosphorus acting with potassium and the effect of phosphorus acting with potassium but in the presence of nitrogen. NPK is the interaction of nitrogen, phosphorus, and potassium and represents the effect of any one of the three fertilizers acting in the presence of the other two. For example, it is the *difference* between the effect of nitrogen acting with phosphorus in the presence of potassium and the effect of nitrogen acting with phosphorus in the absence of potassium.

The significant effects in Table 1-b warrant a discussion.

Only the interaction effect of the fertilizer combination of nitrogen, phosphorus and potassium was significantly different from any other single fertilizer or combination effect in increasing the size of the beets.

The percent sucrose in the beets was significantly lowered by the application of nitrogen fertilizer whether applied alone or in any combination with potassium and phosphorus singly or together. On the average the sucrose was lowered 0.40 percent by nitrogen applications.

The over-all effect of applications of phosphorus was to significantly increase the production of sugar per beet. However, the NPK interaction indicates that phosphorus differs in its effect when it is applied with nitrogen, and when it is applied with nitrogen and potassium.

An examination of the NPK interaction shows that the phosphorus-nitrogen combination actually had a depressing effect, while the phosphorus-nitrogen-potassium combination had a stimulating effect.

Table 2-a contains the means of the leaf analyses for each fertilizer treatment. These means are an average of leaf analyses of samples from

Table 2-a.—Average[1] Leaf Analysis Values[2] by Fertilizer Treatment for Three Samplings[3].

	Sampling Number	Treatments								Average of all Treatments
		ck	n	p	k	np	nk	pk	npk	
% N	1	3.90	4.66	4.26	4.25	4.71	4.60	4.19	4.78	4.41
	2	3.20	3.39	3.21	3.37	3.69	3.41	3.09	3.72	3.39
	3	2.66	2.87	2.50	2.65	2.83	2.85	2.70	2.82	2.73
% P_2O_5	1	0.66	0.73	0.84	0.74	0.92	0.68	0.80	0.96	0.79
	2	0.33	0.31	0.39	0.36	0.46	0.28	0.35	0.45	0.37
	3	0.28	0.28	0.34	0.28	0.31	0.26	0.31	0.32	0.30
% K_2O	1	3.41	3.56	3.56	3.63	3.58	3.58	3.54	3.82	3.59
	2	3.25	2.90	3.61	3.79	3.06	2.96	3.47	3.24	3.29
	3	3.12	3.64	3.97	3.64	3.34	3.43	3.57	3.62	3.54
% CaO	1	0.58	0.48	0.36	0.49	0.47	0.48	0.40	0.27	0.44
	2	1.41	1.45	1.50	1.40	1.14	1.49	1.40	1.18	1.37
	3	2.04	2.14	2.06	2.08	2.00	2.12	2.11	2.03	2.07
% Na_2O	1	2.41	2.17	2.27	2.23	2.34	2.24	2.25	2.18	2.26
	2	4.48	4.31	4.58	4.36	4.49	3.99	4.74	4.29	4.41
	3	6.15	5.84	6.03	5.84	6.74	5.85	6.09	6.22	6.10
% MgO	1	0.61	0.60	0.56	0.57	0.58	0.62	0.56	0.55	0.58
	2	1.15	1.32	1.15	1.16	1.07	1.30	1.27	1.01	1.18
	3	1.96	2.01	1.70	1.83	1.78	2.00	1.72	1.77	1.85

[1] Average of 8 plots for each treatment.
[2] Percent oven dry weight of leaves.
[3] Date of sampling: No. 1, August 13; No. 2, September 4; No. 3, September 26.

Table 2-b.—Significant Differences Between Sums of Four Means Due to Fertilizer Effects for Leaf Analysis Values[1].

Nutr. Anal.	Sampling Number[2]	Main Effects			Interaction Effects				L.S.D.[3]	
		N	P	K	NP	NK	PK	NPK	5%	1%
% N	1	2.16**	NS[4]	NS	NS	NS	NS	NS	.64	.84
	2	1.36**	NS	NS	.88**	NS	NS	NS	.64	.84
	3	.88**	NS	NS	NS	NS	NS	NS	.52	.68
% P_2O_5	1	.28*	.72**	NS	NS	NS	NS	NS	.28	.36
	2	NS	.36**	NS	.28**	NS	NS	NS	.12	.16
	3	NS	.20**	NS	NS	NS	NS	NS	.08	.12
% K_2O	1	NS	NS	NS	NS	NS	NS	NS	.56	.76
	2	—1.96**	NS	NS	NS	NS	NS	.80*	.76	1.08
	3	NS	NS	NS	NS	NS	NS	1.40**	.92	1.24
% CaO	1	NS	—.52**	NS	NS	NS	NS	NS	.36	.48
	2	NS	—.52*	NS	— 68*	NS	NS	NS	.52	.72
	3	NS	NS	NS	NS	NS	NS	NS	.48	.64
% Na_2O	1	NS	NS	NS	NS	NS	NS	NS	.40	.56
	2	—1.08*	.96*	NS	NS	NS	NS	NS	.84	1.12
	3	NS	1.40**	NS	1.16*	NS	NS	NS	1.04	1.40
% MgO	1	NS	—.16*	NS	NS	NS	NS	NS	.12	.20
	2	NS	—.40*	NS	—.64**	NS	NS	NS	.32	.44
	3	NS	—.84**	NS	NS	NS	NS	NS	.40	.52

[1] Percent on an oven dry basis; differences are between means of 32 plots.
[2] Date of sampling: No. 1, August 13; No. 2, September 4; No. 3, September 26.
[3] L.S.D.: Least difference required for significance.
[4] N.S: Non-significant difference.
* Significant at 5% level.
** Significant at 1% level.

eight replicate plots for each treatment and are given for the three sampling dates. Table 2-b lists the significant differences between means due to the seven fertilizer effects for the values in Table 2-a.

Table 3-a is made up of the means of the percent of total nutrients for each fertilizer treatment. Means are given for each nutrient that was examined in this study. They are averages of the means of leaf analyses of samples from the eight replicate plots taken on three sampling dates. Table 3-b lists the significant differences between means due to the seven fertilizer effects for the values in Table 3-a.

Examination of Tables 2-a, 2-b, 3-a, and 3-b reveals a number of significant fertilizer effects on leaf nutrient content and balance.

The addition of nitrogen fertilizer significantly increased the amount of nitrogen in the leaf on all three sampling dates. However, on the second sampling date the significant nitrogen and phosphorus interaction indicated that nitrogen applied with phosphorus was different in its effect than when applied without, irrespective of the presence or absence of potassium. In this instance, nitrogen was much more effective when applied with phosphorus than when applied alone. The percent of nitrogen in relation to the other nutrients present in the leaf was also significantly increased by nitrogen fertilizer.

The amount of phosphorus in the leaf was significantly increased by the addition of phosphorus fertilizer at all three samplings. However, here again, at the second sampling, the effect of applying phosphorus with nitro-

Table 3-a.—Percent of Total Nutrients by Fertilizer Treatment[1]

	Treatments							
	ck	n	p	k	np	nk	pk	npk
% N	23.46	25.62	23.25	24.03	25.81	25.79	23.46	26.21
% P_2O_5	3.01	3.10	3.64	3.22	3.86	2.88	3.42	4.02
% K_2O	23.50	23.71	25.96	25.92	22.97	23.68	24.86	24.66
% CaO	9.69	9.56	9.13	9.31	8.25	9.68	9.17	8.07
% Na_2O	31.34	28.85	30.07	29.17	31.23	28.66	30.74	29.33
% MgO	8.96	9.22	7.96	8.36	7.88	9.30	8.34	7.72

[1] Average of three samplings.

Table 3-b.—Significant Differences Between Sums of Four Means Due to Fertilizer Effects for Percent of Total Nutrients.

	Main Effects			Interaction Effects				L.S.D.[1]	
Nutrient	N	P	K	NP	NK	PK	NPK	5%	1%
% N	9.24**	NS[2]	NS	NS	NS	NS	NS	2.56	3.40
% P_2O_5	NS	2.72**	NS	1.08*	NS	NS	NS	1.08	1.12
% K_2O	—5.24**	NS	NS	NS	NS	NS	5.24**	3.80	5.08
% CaO	NS	NS	NS	NS	NS	NS	NS	3.76	5.00
% Na_2O	—3.24**	3.36**	—3.60**	2.72**	NS	NS	—4.56**	2.00	2.68
% MgO	NS	—3.92**	NS	—1.92*	NS	NS	NS	1.56	2.08

[1] L.S.D.: Least difference required for significance.
[2] NS: Non-significant difference.
* significant at the 5% level.
** Significant at the 1% level.

gen was different than when it was applied alone. This effect was not influenced by potassium and resulted in an increase of phosphorus in the leaf. Phosphorus applications also significantly increased the proportion of phosphorus in the leaves. Once again, a nitrogen and phosphorus interaction is noted and can be interpreted as before. Phosphorus in the leaf was also increased by the addition of nitrogen fertilizer at the first sampling only.

Potassium in the leaf was found to be significantly reduced by the addition of a nitrogen fertilizer only at the second sampling. Further, there was a significant NPK interaction present at this sampling. This same interaction was again found at the third sampling but the significant nitrogen reduction of leaf potassium was absent. The proportion of potassium in the leaf was also very significantly depressed by the over-all action of nitrogen fertilizer additions. Acting with this effect was an NPK interaction.

Calcium in the leaf at the first and second samplings was decreased by the application of phosphorus fertilizer. At the second sampling, this action was influenced by a nitrogen-phosphorus interaction. The proportion of calcium in the leaf was not changed by any of the fertilizer additions.

On the second and third sampling, the sodium content of the leaf was increased by the phosphorus fertilizer treatment. Nitrogen, in contrast, depressed the sodium in the leaf at the second sampling but was ineffective at the first and third samplings. In addition, a nitrogen-phosphorus interaction was noted for the third sampling only. Interesting, also, is the fact that all three fertilizers very significantly influenced the proportion of sodium in the leaf. Nitrogen and potassium depressed this proportion, while phosphorus increased it. A positive nitrogen-phosphorus interaction and a negative nitrogen-phosphorus and potassium interaction were both present.

Only the addition of phosphorus fertilizer affected the magnesium in the leaf. The amount and balance in the leaf were reduced at all three samplings. A nitrogen-phosphorus interaction was also noted at the second sampling and in the percent of total nutrients.

Figure 1 is a plot of leaf nutrient content against the age of the leaf. Each point on the curve is an average of values for all of the 64 plots in the test for that sampling date. These curves show that calcium, sodium, and magnesium increased markedly with age. Potassium showed a decrease at the second sampling, and an increase over the first sampling by the third sampling. Nitrogen and phosphorus decreased, with time. Nitrogen declined rather rapidly, while phosphorus declined more gradually.

It is of interest to note that the correlation coefficients in Table 4 decrease as the season progresses for the correlation of average weight of beet and leaf content of nitrogen, of phosphorus, and of potassium. On the other hand, the correlation between percent sucrose and the same elements, except nitrogen, increase as the season advances. The correlation coefficients relating these two variables, yield and percent sucrose, with calcium, sodium, and magnesium are unaffected by sampling dates. These elements do seem to be related negatively to yield and sucrose with the exception of sodium and percent sucrose at the second and third sampling. Nitrogen in the leaf is related negatively to sucrose but positively related to yield. Phosphorus and potassium show a positive relationship to both yield and suc-

rose. Phosphorus in the leaf appears to be related inversely to calcium and to magnesium and to the sum of these elements in the leaf. Phosphorus in the leaf is also related inversely to the sum of calcium, sodium, and mag-

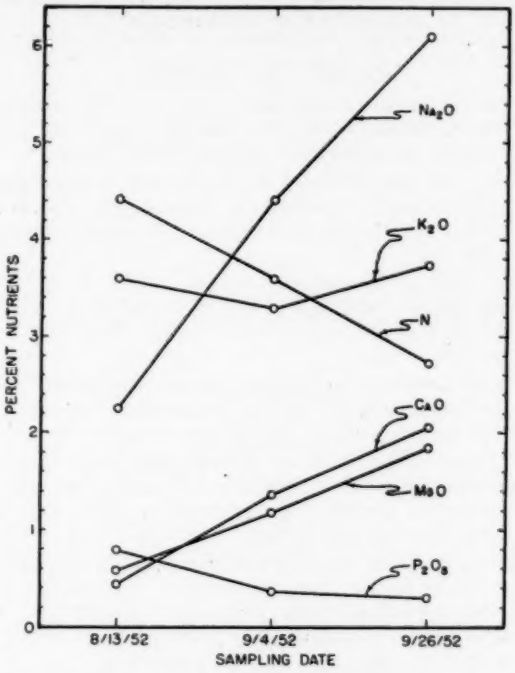

Figure 1.—Change in Leaf Nutrient Content with Age.

Table 4.—Correlations

	Sampling Number[1]	Leaf Content					
		N	P_2O_5	K_2O	CaO	Na_2O	MgO
Average weight of beets	1	.443	.503	.476	—.216	—.276	—.324
	2	.180	.419	.208	—.184	—.248	—.241
	3	.139	.211	.333	—.242	—.220	—.330
Percent sucrose	1	—.119	.165	.197	—.375	—.037	—.391
	2	—.280	.344	.621	—.104	.310	—.079
	3	—.045	.497	.326	—.235	.257	—.398
Sugar per beet	2	—	—	.410	—	—	—
K_2O	2	—.197	—	—	—	—	—
P_2O_5	1	—	—	—	—.363	—	—.430
CaO + MgO	1	—	—.427	—	—	—	—
CaO + Na_2O + MgO	1	—	—.385	—	—	—	—

[1] Date of sampling: No. 1, August 13; No. 2, September 4; No. 3, September 26.

nesium in the leaf. A positive relationship is shown to exist between sugar per beet and potassium in the leaf. Other correlations appear to be insignificant. In these computations, the correlation coefficient, in order to be significantly different from zero, must exceed .250 at the 5 percent level and .325 at the one percent level in absolute value.

Summary and Conclusions

Under the conditions of this test, applications of nitrogen fertilizer affected the percent sucrose in the beet and the amount and proportion of nitrogen, phosphorus, potassium, and sodium in the leaves.

Phosphorus fertilizer influenced the production of sugar per beet, and the amount and balance of phosphorus, sodium, and magnesium in the leaves. Phosphorus also affected the amount of calcium in the leaf, but not its balance in the leaf.

Potassium fertilizer affected the balance of sodium in the leaf and interacted with nitrogen and phosphorus to influence the average weight of beets, sugar per beet, the amount of potassium in the leaf, and the balance of sodium in the leaf.

Leaf analysis values are affected by the age of the leaf. Nitrogen and phosphorus decrease with age, while calcium, sodium, and magnesium show an increase with age. Potassium increased very slightly with age.

Definite relationships are shown to exist between percent sucrose and leaf analysis values and between yield and leaf analysis values. Correlations also exist between the phosphorus content of the leaves and the calcium, sodium, and magnesium in the leaves.

Leaf content and the balance of nutrients in the leaf were markedly influenced by the various fertilizer applications. In addition, leaf content was also related to yield and sugar production. The strength of these relationships would seem to indicate that their use as an index to the fertilizer requirement of sugar beets appears promising.

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Starvation Signs, When and Why?[1]

R. L. Cook[2]

In regions where the climate is similar to that of Michigan, sugar beet leaves should remain green and healthy until harvest time or until they are frozen. Yellow, brown, and misshapen leaves are caused by the attacks of insects and disease organisms or by an unbalanced nutrient supply. The symptoms of nutrient deficiency have been described in a previous volume of the Proceedings (2)[3]. They are relatively easy to recognize.

The purpose of this paper is to point out what soil conditions are most likely to be associated with an unbalanced nutrient status and how such a status may affect the physiology of the plant. The effect of physiological changes, brought about by environmental conditions, on nutrient balance and the appearance of deficiency symptoms will be mentioned briefly. The nutrients will be considered separately except when it is necessary to show how the supply of one may affect the availability of others.

Nitrogen

Nitrogen exists in the soil largely as a constituent of organic matter. The action of soil organisms results in its release as the ammonium (NH_4) and nitrate (NO_3) ions. During early spring, when soils are cold, nitrification is relatively slow. At that time, the young beet plants probably take in considerable ammonium nitrogen. This is evidenced by the fact that nitrogen starvation symptoms are not common during the early seedling stage. As the plants become older their preference for the nitrate form of nitrogen increases.

Since organic matter decomposition, ammonification, and nitrification are caused by living organisms, nitrogen availability in soil is influenced by temperature, moisture, aeration, composition of the organic matter and the supply of mineral nutrients required by the organisms. During cold wet seasons, nitrogen deficiency may occur on soils well supplied with organic matter. This is especially likely to be true if the soil is high in content of clay and if the soil structure has been partly destroyed by excessive tillage. Acid soils are low in mineral nutrients, particularly calcium, magnesium, and potassium. The organic matter in such soil is usually of non-leguminous origin. Such organic matter decomposes slowly and the short supply of bases results in slow nitrification. Starvation for nitrogen is the result.

A lack of nitrogen results in small, light-green leaves. The element is a constituent of chlorophyll so one would expect chlorophyll to vary directly with nitrogen content. The element is readily translocated from old to new leaves. As a result the old leaves lose color faster than do the new center leaves. When deficiency is severe, the death of older, outside leaves usually starts about midsummer. This cuts down leaf area and slows up growth by interfering with photosynthesis.

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[3] Numbers in parentheses refer to literature cited.

Nitrogen-starved leaves grow out in a horizontal position so the old leaves lie almost flat on the ground.

A deficiency of nitrogen results in a lower protein content of the leaves and probably of the roots and in a higher root carbohydrate content. It is a rather generally accepted fact that sugar beets grown directly after alfalfa or those heavily fertilized with nitrogen are lower in sucrose percentage than are those grown in soil with a lower nitrogen level. Accordingly, excessive and/or late applications of nitrogen fertilizer should be avoided.

Phosphorus

Phosphorus compounds in the soil may be roughly divided into two groups, "difficultly available" and "easily available." In the "difficultly available" are included primary and secondary minerals, complex chemical compounds such as hydrated iron and aluminum phosphates, a part of that adsorbed by the clay, and a portion of that held in slow-to-decompose organic matter. The easily available phosphorus occurs in the water soluble form, as calcium and magnesium phosphates, as readily exchangeable ions (H_2PO_4) and as a constituent of easily decomposable organic matter. The proportion of the total which is easily available will be at a maximum and most readily taken into the plant when the soil pH is near 6.8.

A good supply of soil or fertilizer phosphorus hastens the emergence of sugar-beet seedlings and makes them more resistant to disease. Phosphorus-starved plants grow slowly and are very dark green. The leaves stand unusually erect and are often fringed with red. The red color is the result of increased formation of anthocyanin pigment, a common occurrence in phosphorus-starved plants and associated with increased carbohydrate formation.

Seedling starvation for phosphorus is most likely to occur during cold, wet weather, when root penetration is slow. The development of such a condition may be avoided by the application in contact with or close to the seed of plenty of phosphate fertilizer. Heavy contact applications of complete fertilizer may be injurious.

Phosphorus is translocated from old to new leaves. When severe starvation continues after mid-season the older leaves gradually turn yellow. This loss of chlorophyll in turn occurs in younger and younger leaves until even the newest ones become very light green. At that time it is difficult, except by test, to distinguish between nitrogen and phosphorus deficiency symptoms.

Potassium

Potassium occurs in soil as primary and secondary minerals, as exchangeable ions attached to clay and humus, as soluble compounds, and as ions in solution. The potassium required by plants comes from the soluble fraction and that which is held as exchangeable ions. These available fractions may be insufficient for the production of a satisfactory crop even in soils where the total potassium content is very high.

The potassium in potash fertilizer, usually in a soluble form, becomes attached to the surfaces of clay particles and is held there until needed by

the plants or until it passes over into relatively insoluble secondary minerals. When large quantities of potash fertilizers are applied, a considerable portion of the potassium may thus be fixed into an unavailable form. For that reason it is better to fertilize each crop according to needs, than to make large infrequent applications.

Sugar beets require large quantities of potassium. Since the element influences photosynthesis or rate of CO_2 assimilation and thus affects carbohydrate formation, this is to be expected. Starvation signs may appear any time after the first few weeks of growth. They seldom show up during the seedling stage as is the case with nitrogen and phosphorus.

Potassium is readily translocated in the plant. It is highly essential for new growth, as indicated by its high concentration in meristematic tissue. As intake through the roots becomes insufficient for growth requirements, potassium moves out of the older leaves to be translocated to the new leaves emerging from the center of the crown.

As the older leaves continue to enlarge, the growth is, of course, at the tip and along the sides. The small amount of potassium left in that region is soon exhausted and yellowing results. After the marginal areas turn yellow, expansion stops and the leaf becomes crinkled because the cells in the central portion continue to enlarge. In all species of plants, crinkled, older leaves with yellow margins are reliable signs of potassium starvation.

Manganese

To be available to plants, manganese must exist in the soil as a soluble salt, as the exchangeable ion, as a part of easily decomposable organic matter, or as an easily reducible oxide. Manganese is readily oxidized to the manganic form. Under certain soil conditions manganic manganese is reduced to the manganous form. Reduction is favored by acid soil conditions, lack of available soil phosphorus, low temperature, poor aeration, and the presence of reducing compounds.

Sugar beets thrive under conditions which bring about maximum oxidation of native soil manganese, namely high lime, plenty of soil phosphorus, and good aeration. It is logical that, on some soils, the native manganese might be so completely oxidized as to result in manganese starvation. This is a common occurrence on several Michigan soils where sugar beets are grown.

The role of manganese in the plant is not clearly understood. McHargue (5) suggested in 1923 that manganese performs a function in photosynthesis. This may be true as a deficiency results in a characteristic yellowing of the younger (not always the youngest) leaves. In sugar beets, the leaf tissue between the veins loses chlorophyll until the leaf surface takes on a mottled appearance. The mottling is uniform over the entire leaf. The condition develops slowly and leaves may maintain the mottled appearance for a long time before they become necrotic.

Some workers contend that manganese increases the activity of oxidizing enzymes in plants. Others look upon it as a regulator of the intake and state of oxidation in the plant of certain other elements, especially iron.

There is considerable evidence (7) that manganese serves as an oxidizing agent to keep iron in the ferric state so it does not become toxic. In other words, manganese deficiency may actually be iron toxicity. Some investigators have disagreed with this explanation but most of them agree that some relationship does exist between the two elements. Perhaps some of the confusion results from the fact that the symptoms of starvation for manganese or iron are very similar and are also quite similar to those which indicate toxicity caused by excesses of either one.

Perhaps strength is given to the iron oxidation theory by the fact that an excess of manganese causes an appearance which is similar to if not identical with the symptoms of iron deficiency. This has been demonstrated in the Michigan Experiment Station greenhouses.

Boron

Boron occurs in soil as the primary mineral tourmaline, as complex chemical compounds and as a part of organic matter. The total quantity of soil boron is of little importance. The important point so far as plants are concerned is its state of availability. Observations and experiments in Michigan show that boron deficiency occurs only on soils where the lime requirement is low or nil. When soluble boron (borax or boric acid) is applied to such soils it becomes *unavailable* in a very short time (3). These studies have led to the general recommendation that boron be included in all Michigan sugar beet fertilizer. Incidentally, sugar beets are grown successfully on only high lime soils.

Various investigators have reported certain ratios between quantities of boron taken in by plants and the intake of such elements as calcium, magnesium, and potassium. As calcium intake increases, the intake of boron decreases. Wide calcium boron ratios in boron-sensitive plants are accompanied by the occurrence of boron deficiency symptoms. This has been shown by several investigators. Evidence has also been presented that magnesium may affect boron availability in the same manner as does calcium and that the effect of potassium may be the reverse under certain conditions and similar under other conditions.

A deficiency of boron causes a breakdown of the cells in the meristem tissue. This causes "disease" of sugar beets which has been termed *heart rot*. It was so-called long before Brandenburg (1) showed that the "disease" could be prevented by adding soluble boron to the soil.

That boron is not translocated in the plant is indicated by the fact that the symptoms of deficiency occur first on the youngest leaves. Cross cracks appear on the concave side of the petioles of such leaves and they develop faster on one side than on the other. This must be due to an uneven disintegration of the meristem cells from which the leaves started. The visible effect is a twisting of the petioles and/or midribs.

The disintegration of meristem cells within the fleshy portion of the beet root results in the formation of large amounts of cork tissue, nature's way of separating dead from living cells. Such tissue is, of course, low in

sucrose content. The result is a general decrease in the value of the roots. Increases in sucrose content as great as 4 percent have resulted from applications of borax (4) to soils which otherwise produced boron-deficient beets.

Calcium and Magnesium

This paper would not be complete without a brief consideration of these important elements. They exist in the soil as a constituent of minerals and organic matter and as ions attached to the exchange complex. Calcium and magnesium are plentiful in humid region soils which are above 6.0 to 7.0 in pH value. They may be deficient as a nutrient for some crops in strongly acid soils or in those of high pH where there is an excess of sodium.

Sugar beets require plenty of calcium. The element becomes a part of cell walls and plays an important role in regulating the pH of cellular tissues. It is not translocated from old to new tissue. As is true with boron, it is necessary to maintain a continuously available supply in the root medium and as soon as the supply fails, the new leaves are affected. They become chlorotic between the veins in much the same pattern as described for deficiencies of manganese and iron. In the case of sugar beets, the young calcium-deficient leaves become necrotic at a relatively early age (2).

This fact that sugar beets are sensitive to a lack of calcium probably accounts quite largely for the fact that they do not thrive on acid soils.

Magnesium exists in the soil in much the same manner as does calcium. Furthermore, the two elements are quite similar insofar as certain chemical reactions are concerned. In other respects, however, they are quite different. The results from many investigations indicate that a certain calcium-magnesium ratio is desirable and that the optimum ratio varies for different plants. As the ratio becomes too narrow, calcium starvation shows up and as it becomes too wide the plants show signs of magnesium starvation. A soil test for one element means little, then, unless the effective supply of the other is also determined.

Magnesium is a constituent of chlorophyll. One would then expect the supply of the element to affect the color of the leaves. This is true, but to no greater extent, probably, than does potassium. In fact, magnesium deficiency symptoms are generally quite similar to those caused by a deficiency of potassium. The difference lies only in a slight mottling of the central portion of those leaves deficient in magnesium. The yellow blotches in the magnesium-deficient leaves later become necrotic and the tissue disintegrates.

Magnesium performs other roles in plants. Truog, et al. (6) have shown that, in the case of peas, it becomes important as a carrier of phosphorus. Like calcium, magnesium excess affects boron nutrition and indirectly brings about heart rot of sugar beets. Before symptoms appear, a shortage of magnesium may be predicted when soil tests reveal the presence of relatively high levels of either calcium or potassium.

Summary

An unbalanced nutrient status is sure to upset plant metabolism. This may be in the form of what may be considered normal deficiencies or in the form of deficiencies induced by an abnormal supply of another nutrient. In any case, photosynthesis is interrupted and leaves turn yellow. The pattern of yellowing varies with different nutrients. Typical among those which are readily translocated and which affect older leaves first are nitrogen, phosphorus, potassium, and magnesium.

The elements manganese, calcium, iron, and boron are among those which are not readily translocated and which first affect the meristematic tissue.

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I. The Effect of Fertilization on the Glutamic Acid Content of Sugar Beets in Relation to Sugar Production. II. Nitrogen Fertilization in the Woodland, California, Area

LUCILE R. HAG, ALBERT C. WALKER, AND M. LOUISA LONG[1]

Nitrogen fertilization is essential for an optimum sugar crop in the Woodland area of the Sacramento Valley (1-6)[2]. At present, from the standpoint of both grower and processor, the optimum crop is the one which produces the maximum sugar tonnage per acre from the minimum amount of fertilizer. Inability to predict the best fertilizer level makes a conservative fertilizer policy reasonable. On the other hand, since glutamic acid, a by-product in the sugar process, can be increased by nitrogen fertilization (2, 4, 7) it is possible that a more liberal fertilizer usage might be recommended.

Before an accurate economic re-evaluation of the beet crop can be made in terms of both sugar and glutamic acid, certain fundamental information must be available regarding the effect of nitrogen fertilizer on both of these materials. To that end, some of the studies carried out in this area between 1946 and 1951 will be reviewed.

The following phases of the problem have been investigated:

1. Response to various levels of N fertilizer[3].
2. Response to various levels of N at different harvest dates.
3. Response of different varieties at various levels of N.

Response to Nitrogen

The glutamic acid values from 11 fields fertilized with 0, 80, 160, and 240 pounds of nitrogen per acre are shown in Table 1. Smaller increments, 50, 75, 100, 125, and 175 pounds N per acre were applied in the fields shown in Table 2.

The fertilizer, ammonium nitrate, was applied as a side dressing at thinning time. The field techniques and analytical methods for the measurement of glutamic acid have been described previously (4).

Fertilizer nitrogen produced a significant increase in glutamic acid in 15 of the 16 fields studied. Only two fields showed any significant deviation from a straight line response when glutamic acid was measured on a logarithmic scale, and only two fields showed a tendency toward decreased response at higher N levels. Amounts of nitrogen fertilizer larger than those used in these tests would be needed generally in order to bring glutamic acid to a maximum.

The sucrose concentration in all but one of these fields decreased regularly with increasing nitrogen, but the increase in yield prevented a sig-

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[2] Numbers in parentheses refer to literature cited.

[3] No response to phosphate either in sucrose or glutamic acid has been found in this area.

nificant loss in tons sugar per acre in more than half of the fields at the higher nitrogen treatments. There is a clear cut, close relationship in the sugar and glutamic acid responses to nitrogen. Fertilization increases weight and glutamic acid but decreases percent sucrose.

Since benefits from glutamic acid production do not appear to fall off even at levels of 240 pounds N per acre, a fair return from the glutamic acid crop should remove much of the calculated risk of recommending a fertilizer usage somewhat above that for maximum sugar tonnage per acre. In evaluating the glutamic acid crop, percentage increases in concentrations obtained in beets are more important than the actual glutamic acid value itself. Such percentage increases should amount to similar increases in the grade of concentrated Steffens filtrate.

In order to get some idea of the nitrogen level required for maximum glutamic acid response, one field was fertilized (ammonium nitrate side dressed when the beets were one inch in diameter) with 625, 1250, 1875, and 2500 pounds of N per acre. The results (Table 3) were most interesting. Even at these extremely high levels of nitrogen the beets were not killed and differences in stand were insignificant at the different levels of treatment. The beets were somewhat smaller at levels above 625 pounds per acre and sucrose concentration also appeared to level off above this point; glutamic acid levelled off at the 1250 treatment.

Table 1.—Effect of Nitrogen Fertilization on Percent Glutamic Acid in Sugar Beets.

Year	1946	1947V	R	H	W	K	M	C	1948	1950	1951
Pounds N/Acre					Percent Glutamic Acid						
0	0.14	0.26	0.08	0.07	0.03	0.12	0.12	0.12	0.06	0.05	0.14
80			.14	.12	.04	.20	.20	.21	.11	.08	.25
160	.26	.34	.17	.16	.06	.31	.24	.31	.19	.15	.28
240			.23[1]	.23[1]	.08	.37	.34[1]	.36	.19	.20[1]	.31[1]

[1] Significant decrease in Tons Sugar Per Acre.

Table 2.—Effect of Nitrogen Fertilization on Percent Glutamic Acid in Sugar Beets.

	1948				
Pounds N/Acre	Ri	G	B	L	Be
50	0.06	0.32	0.20	0.09	0.29
75	.08	.34	.21	.12	.31
100	.09	.36	.23	.12	.31
125	.10	.38[1]	.25	.14[1]	.26[1]
175	.15	.44	.30[1]	.15	.29

[1] Significant decrease in Tons Sugar Per Acre.

Table 3.—Effect of High Nitrogen Fertilization on Percent Glutamic Acid in Sugar Beets in 1949.

Pounds N/Acre	Percent Stand	Tons Beets/Acre	Percent Sucrose	Percent GA
0	142	19.2	15.8	0.22
625	144	23.9	12.6	.47
1250	146	20.5	12.9	.54
1875	141	21.0	12.5	.56
2500	150	19.4	12.6	.61

The 0.6 percent concentration of glutamic acid which was the maximum for this field should not be considered indicative of the maxima possible from all fields. Considerably higher concentrations have been observed in fields in other areas and from relatively small amounts of fertilizer. Conversely some of the fields studied (2) would probably never have reached 0.6 percent glutamic acid even with these enormous amounts of fertilizer. Such a determination of maximum glutamic acid may be a ready means of locating fields or areas with unsatisfactory growing conditions resulting both in low glutamic acid and in low sucrose.

It appears that in general, any field which responds to nitrogen fertilization with an increase in tons of sugar per acre will also give a striking increase in glutamic acid. This increase in glutamic acid will continue well past the optimum treatment for production of sugar.

Effect of Harvest Date

If the amount of applied nitrogen is to be increased it is important to know whether harvest date need be delayed for most advantageous utilization. The response of sucrose and glutamic acid to different levels of applied nitrogen at different harvest dates has been studied in two fields. In the 1947 experiment (4), we were interested in determining the response in young as well as harvestable beets. Consequently, two of the four harvests were made earlier (June and July) than the usual harvest period for spring planted beets in this area. Average decrease in glutamic acid during the harvest period was 12 percent. In the 1951 experiment, all three harvests were made during the regular harvest period. The description of this field and the yield and sucrose data are being reported by Hills, Burtch, Holmberg, and Ulrich (8). They found that the increase in yield between the harvest dates, was greater for US 22/3 than for US 35/2. Since no such difference between varieties was observed in the glutamic acid responses at different harvest dates, the data for both varieties have been averaged in Table 4.

Table 4.—Effect of Date of Harvest on Glutamic Acid Concentration at Different Levels of Nitrogen Fertilization.

	Pounds N/Acre			
	0	80	160	240
Harvest Date	Percent Glutamic Acid			
9-28-51	0.20	0.22	0.31	0.32
11-1-51	.16	.25	.28	.35
12-13-51	.14	.25	.28	.31

Glutamic acid generally decreases gradually during the harvestable period, but this decrease assumes significance only at the lowest level of fertilization. The 30 percent decrease in the concentration of glutamic acid in the unfertilized beets produced a significant harvest date—nitrogen interaction even though the field was a highly fertile one (yielding over 30 tons per acre). The shortage of nitrogen indicated by the low glutamic acid value of the unfertilized plots at the last harvest was not severe enough to decrease root growth during the harvest period. Yield of the unfertilized

plots increased 5.8 tons per acre over the harvest period as compared to 6.0 tons per acre at 240 N. As sucrose also increased approximately 1 percent during the harvest period, glutamic acid is the only factor favoring early harvest of beets, and this only at lower nitrogen levels—in this test the average sucrose of the check plots was 13.9 percent by the September harvest.

There was an average gain of 0.8 tons sugar per acre between the first and second harvest, and an additional gain of 0.3 tons between the second and last harvest. It is clearly evident that the applied nitrogen was utilized more completely at the later harvest dates and the optimum crop for both sugar and glutamic acid will be realized at a late harvest date.

Nitrogen fertilization in this fertile field caused a decrease in tons sugar per acre, but the decrease is relatively small (0.3 tons per acre) up to 160 pounds of nitrogen. If the value of the glutamic acid produced was taken into consideration, the best crop would be produced at the neighborhood of 160 pounds of nitrogen. This may be compared to the more than 250 pounds of nitrogen which such a crop removes from the landowner's soil.

Varietal Differences

We have always been interested in determining whether there was any difference in the glutamic acid content of different varieties of sugar beets or in their response to nitrogen fertilization. A large number of experiments have been carried out testing most of the commercial varieties and those being tested for commercial possibilities in this area. In practically all cases, the results have been negative or inconclusive. There is some evidence that US 75 is lower in glutamic acid content than other commercial varieties. In the 1951 Variety—Harvest date experiment just described, the "sugar type" variety US 35/2 had a significantly higher glutamic acid content (0.26 percent) at all treatment levels than the "yield type" US 22/3 (0.23 percent). The difference is small and might possibly be reversed under other growing conditions. There was no difference between the varieties in response to the different nitrogen levels.

This does not imply that varietal differences cannot be produced. Highly significant and large differences in the glutamic acid content of inbred sugar beet varieties have been shown (9). Sugar type varieties tend to have higher glutamic acid.

Since field experiments had failed to indicate any difference in the response of commercial varieties to nitrogen fertilizer, a sand culture experiment was carried out in 1951 using breeding strains expected to show wide variation in glutamic acid content. The beets were grown under conditions similar to those described earlier (10). Despite highly significant differences between varieties in both glutamic acid and sucrose and significantly larger beets in one variety, no differences in the nitrogen response of the strains could be detected (Table 5). The 100 percent increase in glutamic acid, 50 percent increase in root weight, and a two point drop in sucrose percentage applied to all six strains on tripling the available N.

Table 5.—Varietal Responses at Two Levels of Nitrogen.

	Nitrate in Nutrient, Millimols Per Liter					
	0.4	1.2	0.4	1.2	0.4	1.2
Variety	Percent Glutamic Acid		Percent Sucrose		Pounds/beet	
106	0.11	0.20	16.4	14.4	1.55	2.44
93	.19	.46	16.0	14.1	1.51	2.39
US 33/2	.14	.27	15.5	13.9	1.54	2.52
109	.11	.25	16.2	14.3	2.00	2.95
135	.19	.50	16.1	13.3	1.62	2.56
102	.12	.25	17.0	15.3	1.75	2.39

12 beet averages. High potash and phosphate nutrient applied twice daily. Approximately one liter available per application.

Summary

The concentration of glutamic acid in sugar beets increases regularly with increasing amounts of nitrogen fertilizer. Although glutamic acid decreases slightly during the harvestable period, the effect is most pronounced at low nitrogen levels. Higher glutamic acid values would tend to counteract losses due to premature harvest only in cases where the nitrogen status was sufficiently low. There are no large differences in the glutamic acid content of the present commercial varieties used in this area, nor in the responses of these varieties to increasing amounts of applied fertilizer.

Nitrogen fertilization increases weight and glutamic acid, but decreases sucrose concentration. This very close relationship between sugar and glutamic acid suggests that the crop should be evaluated in terms of glutamic acid as well as sugar. With a fair return from glutamic acid, a higher fertilizer usage might be recommended advantageously.

ACKNOWLEDGMENT

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The Significance of Single Gene Reactions In Sugar Beets

F. V. Owen[1]

The gene has been defined as "a unit of chromosomal structure with the vital property of specific self-duplication" (20)[2]. An essential property of the gene is "that of organizing materials around it in a highly specific molecular pattern" (20). In 1941 Beadle and Tatum (2) began a remarkable series of publications on work with genes in relation to specific biochemical reactions in the common bread mold Neurospora. Further work led Horowitz in 1948 (6) to the "one gene-one enzyme hypothesis,"—one may say "the gene is the self-duplicating producer of an enzyme" (20). After reading much critical discussion (3) of this hypothesis one is obliged to accept questions here and there. In some cases, for instance, two or more genes appear to be involved in the production of one enzyme. However, all this evidence seems to lead only to a still better and more simple connotation "one gene, one biochemical process."

One Gene, Other Genes and Environment

There is a great advantage that goes with simplicity in the study of heredity. Gregor Mendel demonstrated this fact most beautifully in his original work with garden peas. When too many genes are studied simultaneously the problem soon becomes too complex for most geneticists to analyze. As one gene begins to operate in the development of a new individual, its chemical environment is determined not only by itself but by many other genes, by heritable substances transmitted through the cytoplasm and by the external environment.

In a study of specific control of biochemistry in Neurospora the role of environment has been of particular importance. Besides the necessity for critical control of nutritional factors, temperature sometimes plays such an important role that the term "temperature mutants" has been coined in reference to 26 genes in Neurospora (7) whose behavior can be studied effectively only at rather specific temperatures.

In spite of the interesting connection between the gene and a specific biochemical process, studies in higher plants have been badly neglected. Nutritional disturbances are usually thought to be too involved to even think of postulating the action of a single gene. However, Weiss (23) discovered a gene in soybeans which was shown to play a most important role with regard to iron requirement. Pope and Munger (14, 15) also found remarkable relationships for magnesium and boron deficiencies in celery, similar to Weiss' discovery in soybeans. The boron-susceptible line made a growth comparable to that of other lines in a normal culture solution (0.5 p.p.m. of boron) but when grown at a concentration of 0.01 p.p.m. this susceptible line showed severe boron deficiency symptoms not shown by resistant lines. This character, like that for magnesium deficiency, was

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[2] Numbers in parentheses refer to literature cited.

found to be inherited through a simple recessive gene. In F_2 populations good 3:1 ratios of boron-resistant to boron-susceptible lines were obtained and in backcross populations 1:1 ratios were obtained.

It has been pointed out (22) that most inorganic nutrients required by plants contain atoms which occupy key positions within the enzyme molecule. Boron and magnesium probably play critical roles in gene enzyme relationships in celery. However, much work remains to portray the complete biochemical picture. Weiss (23) showed that in soybeans inefficient lines for ion utilization developed a higher pH in aerial tissue which was probably related to iron solubility.

To the statistician the clear-cut segregation made possible by the action of single genes, or in some instances by the well-defined action of two or more genes, is known as discontinuous variation. An appraisal of this situation by Nelder (10) reads as follows:

"The statistical models belonging to the analysis of discontinuous variation in genetics have an elegance and exactness which are rare in the field of applied statistics. This is partly due to the qualitative nature of the characters usually investigated and partly to the random processes inherent in meiosis and fertilization . . .

"The contrast between this state of affairs and that found when continuous variation obtains is indeed striking. The assumption that continuous variation represents the combined effect of polygenic inheritance and a blurring environmental overlay, though necessary as a basic postulate, is too vague to allow analysis to proceed very far. Inefficient *ad hoc* methods of analysis have to be used in default of anything better."

Single Genes in Beets

In beets the geneticist has not yet approached the subject thoroughly enough to even begin a good discussion of biochemical specificity if we look at the problem from a strictly chemical point of view. However, we do know that we have been dealing with some rather specific biological reactions the knowledge of which, with some concentrated effort, might be carried much further.

There are some well-known genes in beets, but most are associated with some sort of anomaly (13, 18). The gene *R* for red hypocotyl and crown bud color does not involve anything abnormal, so this gene is one of the most easily investigated. This gene is useful to the sugar beet breeder as a marker. In crosses involving *R* and *r* beets F_1 hybrids are easily recognized by the dominant *R* hypocotyl color in the seedling stage. This gene is also useful in detecting the percentage of crossing in certain situations and the percentage contamination in other situations. In larger vegetative beets the *R* individuals are easily recognized by red color in the crown buds. However, there comes a time in the early formation of the seed stalks when the red color disappears and it may be impossible to distinguish *R* beets from *r* beets.

The *R* locus in beets is probably a variable locus. Some *R* lines have much darker pigment than other *R* lines and in some instances the pigment

extends from the crown buds well up into the petioles. Keller's work (8) and other corroborative evidence (13) indicate that these variations are due to allelic differences and not necessarily due to secondary genes. In cooperation with one additional gene for extension of pigment, the gene *R* becomes responsible for the deep red color in red garden beets and in certain varieties of fodder beets. The chemical composition of the anthocyanin-like pigment of these beets has received considerable attention. It is characterized by an NH_2 group in its structure which is not associated with the usual anthocyanin pigments.

Several genes in beets seem to be especially affected by temperature. In our inbreeding work at Twin Falls, Idaho, with curly-top-resistant beets, we have frequently seen populations segregating for a chlorophyl deficiency in which red anthocyanin pigment accumulates and a foliar breakdown occurs during the month of September. Earlier, these same beets were perfectly normal and later, during October, normal leaves again appeared. Savitsky (17) reports an interesting recessive gene found in Russia which he designated *re* for reduction of foliage. This gene also finds expression relatively late in the season at which time lance-shaped rudimentary petioles replace the normal leaves. Undoubtedly, many very interesting genes could be studied in beets by proper control of growing temperatures.

The Gene B for Bolting

The dominant gene *B* for bolting in beets is an example of a well-established gene whose reaction is delicately affected by the presence of other genes and by environment. In fact, these relationships are so intimate that had it not been for the linkage between *B* and the color gene *R* which Abegg (1) established, we may not have taken the trouble to prove that a single major locus is involved in the difference between annual *BB* and biennial *bb* beets. To distinguish gene *B* from other genes which may also affect rate of seed stalk initiation and reproductive development, it is well to emphasize that gene *B* exhibits its full potentialities only in a rather special environment. It is essentially a temperature gene in that it replaces the usual thermal induction in ordinary biennial beets.

The annual *BB* beets studied most extensively at the Salt Lake City Station were obtained from Dr. Munerati in 1932. Munerati had been able to reproduce seven generations of this annual beet in a single year (9). We immediately recognized the advantage of this annual gene for many theoretical problems where time required for reproduction is important. A little later, it was found that annual male-sterile beets were very useful in speeding up reproduction to facilitate classifications of progenies being tested for the type O genotype (11) used in the development of cytoplasmic male-sterile lines. Later it was visualized that annual inbreds (12) may be established to represent valuable breeding stocks without any material difference between the biennial inbred and its annual equivalent, except for the presence of the gene *B*, to speed up generations of reproduction. With these important implications, a very careful study of the physiology and biochemistry associated with this annual gene becomes a matter of exciting interest.

Munerati's annual *BB* beets planted in the field at Salt Lake City in early April behave strictly as annuals. Even when planted here in early June, they also behave as annuals in field plantings, in that all the beets initiate seed stalks, but later on these seed stalks may turn somewhat vegetative. When planted in early August, the annual *BB* beets are no longer uniform and the effect of secondary genes becomes evident. In August plantings, some of these Munerati annual beets are fast bolters, some are slow bolters, and a few fail to bolt at all. In September 1 plantings, a few of these annual beets bolt, but the majority remain vegetative. A September planting of the same beets at Riverside, California, remained completely vegetative, with well-developed rosettes and with roots nearly as large as biennial beets planted at the same time.

Heterozygous *Bb* beets are much more complicated to deal with than homozygous *BB* beets. Much of this complexity is probably due to the influence of modifying genes introduced with the *b* gene. Usually the heterozygous *Bb* beets planted at Salt Lake City in April also behave strictly as annuals but in June and July plantings some plants are annuals and others behave as biennials. In August plantings, most of the *Bb* beets remain vegetative. Therefore, under field conditions in summer plantings, it becomes impossible to establish any reliable genetic ratios in segregating populations, so much so that an investigator could easily become discouraged and release the whole situation by assuming multiple factors and continuous variation. In fact, without a controlled environment, continuous variation unquestionably does prevail.

Careful genetic investigations can be conducted with annual beets only under a controlled environment and more should be learned about the exact requirements. We do know that by the use of warm greenhouse temperatures and continuous illumination annual *BB* beets bolt quickly at all times of the year and heterozygous *Bb* beets, so far as they have been studied, also bolt and reproduce satisfactorily. After two backcrosses to *bb* genotypes it has been possible to clearly separate *Bb* genotypes from *bb* genotypes although in some cases more time is required. However, with temperatures at 75° F. or above, most *bb* genotypes never initiate stalks. Therefore, the final segregation appears to be entirely clear cut.

Fundamentally, the gene *B* seems to remove all necessity for thermal induction. It may someday be possible, when more is learned about hormones or hormone-like substances responsible for flowering, to substitute an artificial chemical spray or inoculation that will substitue for the specific gene in annual beets.

Without a known chemical compound at hand to replace photo-induction, Stout (21) was able to demonstrate the critical action of a biochemical substance by grafting biennial beets to annual beets. Biennial beets bolted readily when grafted to annuals when the biennial rosettes were held in complete darkness by means of black cloth bags used for covering. With this arrangement, the chemical substance associated with photo-induction in annual beets was translocated to the biennial beets. This is not just the same as isolating and crystallizing a flowering hormone, but it does bring one very close to an important biochemical process and opens up a most fruitful field for future investigations.

Discussion

It is a long way from the single gene in the chromosome to the fully developed character. Considering the important effect of secondary genes and environment, it is remarkable that we are able with such little effort to see so many well-defined single gene reactions in mature individual plants and animals. This can only be attributed to the striking biochemical specificity of single gene reactions. A single biochemical reaction is probably only one step in the development of an individual but it may be the one critical, determining step. With better control of environment and with better knowledge of secondary gene influences, one should be able to make rapid advances.

A method of investigation which removes the effect of secondary genes and greatly facilitates the study of single gene reactions is the backcross method. This method, plus careful environmental control, brings the effects of single genes into full view, whereas they may be unnoticed otherwise. In conjunction with the backcross method the annual gene and a gene for Mendelian male sterility (12) constitute invaluable tools for genetic work with sugar beets. The gene for male sterility effects emasculation and the annual gene hastens reproductive development. A backcrossing procedure with these tools should be of particular interest in studying many problems. It should be invaluable in studying disease resistance.

Where at first several genes seem to be necessary for resistance to a particular disease organism, it is a great challenge to discover one single major gene that accomplishes the same results. For instance, in wheat, Briggs and Holton (4) found single genes for resistance to 25 races of bunt (*Tilletia caries* and *T. foetida*). The idea of having one major gene for over-all resistance has great advantages over the method of searching for separate genes for each new race or variation in the disease organism. In the search for these major genes it is sometimes necessary to go to wild species. Classical examples of major genes for high disease resistance are reported by Clayton (5) from wild species of tobacco. In some instances, Clayton found that these major genes produce complete immunity, whereas, genes from domestic species produce only intermediate or partial resistance.

Production of specific mutations by means of X-rays, or other artificial means, is also receiving serious consideration by more and more geneticists. One example in beets is the production of a specific mutation for Mendelian male sterility by means of X-rays (12). With more specific knowledge of genes desired, of environmental control, plus better genetic procedures (such as the backcross method), it is now possible to make definite plans for artificial production of mutations which can be of great interest and of great value.

The discovery of the gene for the monogerm seed character in beets (17) dispels any idea that single genes are not important. Furthermore, the monogerm character is an excellent demonstration of the philosophy that characters produced by single major genes may be much more valuable than characters requiring two or more genes for their expression. With only one major gene involved the problem of producing commercial mono-

germ sugar beet varieties becomes a straight-forward problem which can be attacked with great confidence. If this problem were complicated only to the extent of requiring two genes instead of a single gene, the problem of producing satisfactory commercial monogerm sugar beet varieties would be much more complicated and would require much more time.

Summary

A limited review of the literature on single gene reactions is presented, showing a remarkable relationship between a single gene and a single biochemical process. It is shown that the reaction of a single gene is determined by the presence of other genes and by environment. Particular reference is made to the gene *B* in beets for "bolting" or the annual growth habit, which is in direct contrast to the biennial growth habit. Under a controlled environment with long photoperiods and warm temperature, it has been possible to conduct effective studies with the reactions of this gene. This example is believed illustrative of what might be accomplished by studies under a controlled environment with many other important genes in beets. The backcross method is described in relation to development of isogenic lines which differ only in the important gene or genes under investigation. Reference is made to two genes in beets which greatly facilitate the backcross operation: first the gene *B* for rapid reproduction, second, a gene for Mendelian male sterility for emasculation purposes.

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Inter-Relation Between Weight of Seed and Fruit and Utilitarian Characters in Inbred Lines and Hybrids of Monogerm Sugar Beets

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Introduction

The original monogerm line SLC 101 *mm* bears small fruit. The weight of 1,000 fruits of this line hardly reaches 5-8 grams. Therefore, some apprehension arose that monogerm fruits would not be valuable because of their small size. A study of F_2 and F_3 lines obtained from hybrids from multigerm varieties to SLC 101 *mm* showed that monogerm lines with comparatively large fruits can be developed. The weight of 1,000 fruits in such monogerm lines varied from 20 to 25 grams. The fruits of these lines could be screened to a definite size class which distinguished them not only in the size of fruits, but in the size of germs. The fruits of the different size classes will have the same or similar genotypes because they were derived from the same inbred lines, and the differences in their size are due mainly to their location on the branches. If the differences in productiveness of beets grown from different size classes of the same inbred line are observed, such differences must be attributed to the influence of size of the fruits themselves.

Significance of the size of fruits in agriculture has interested investigators for several decades. Experiments with multigerm beets were conducted in all countries interested in sugar beet growing. The results were contradictory. The controversies could be partially explained by the fact that in multigerm beets the size of seed balls increases. On account of enlargement of size of flowers in the flower cluster and of the increase in the number of flowers simultaneously, variation in the number of flowers in the flower cluster observed the influence caused by the size of germs themselves. Monogerm fruits represent a valuable material for the examination of the influence of size of fruits and germs on the development of beets.

Materials and Methods

Nine S_3 monogerm lines obtained at the Salt Lake City Station from crosses of different multigerm sugar-beet varieties to SLC 101 *mm* were used in this experiment. These lines of different origin were different also in sugar content and in yield, but they all developed large fruits. The mean weight of 1,000 fruits varied in these lines from 15 to 19 grams.

Besides these nine lines, monogerm seed was obtained from male-sterile monogerm beets pollinated by monogerm inbreds. Dr. F. V. Owen supplied hybrid seed from monogerm male-sterile beets obtained after pollination by multigerm beets. The seed of each sample was screened to definite size classes: large, medium, and small. Seed of three classes from

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[2] Numbers in parentheses refer to literature cited.

each line was planted in three replications in Salt Lake City, Utah, and in Twin Falls, Idaho. Equal portions of large and medium seed were planted, but the weight of the small seed portion was higher to avoid thin stands.

Experimental Results

Variation in the weight of germs after the fruits were screened to size classes.

The size classes obtained after screening the fruits of the same monogerm lines consisted of fruits of different size. One thousand fruits in the "large-sized" class weighed from 18 to 24 grams. These fruits contained very large germs. The weight of 1,000 germs exceeded 2.5 grams and sometimes reached 3.5 grams (Table 1).

Table 1.—Relation Between Weight of Fruits and Germ in Large, Medium, and Small Sized Seed Groups of Nine Monogerm S_3 Lines.

Weight of 1,000 fruits in grams	Weight of 1,000 germs in grams: 1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50
24										1	
23									1		
22										1	
21									1		1
20								3			
19							1				
18											
17											
16											
15											
14			2	2							
13			3								
12			1								
11		1	1								
10	1	3									
9		5									
8	1										

Size of Seed	Weight per 1,000 Germs Mean	Germs Standard Error	Fruits Mean	Fruits Standard Error
Large	2.97	0.11	21.1	0.53
Medium	1.56	0.33	13.1	0.35
Small	1.19	0.03	9.4	0.27

One thousand fruits in the "medium sized" class of the same line weighed from 11 to 14 grams. The weight of 1,000 germs in this class varied from 1.5 to 2.0 grams.

One thousand fruits from the "small-sized" class weighed from 8 to 11 grams and 1,000 germs in this class weighed only 1.25 to 1.50 grams.

Seed germination

Careful germination tests of samples of monogerm seed were carried out by C. H. Smith. Germination ability varied in different monogerm lines. No differences between different size classes were observed in the final percentage of germinated seed in all the nine monogerm lines, although the smaller seed started to germinate a little earlier (Table 2).

Table 2.—Germination of Seeds in Different Size Classes of Monogerm Inbred Lines.

Size class	Germination on 2nd day	Germination on 5th day	Final germination	Germination in percent of filled fruits
	Percent	Percent	Percent	
Large fruits	4.4	64.8	79.7	94.2
Medium fruit	5.2	73.7	81.2	96.2
Small fruit	9.7	66.2	79.4	96.0

Thickness of stand

The seed from the "large-sized" class in all lines gave a lower stand than the seed from the "medium-sized" class, and even from the "small-sized" class. This appearance was observed in Salt Lake City and also in Twin Falls (Table 3).

Large fruits produced fewer plants per plot, not only in monogerm inbred lines, but also in male-sterile hybrids where the embryos were heterozygous (Table 3).

Sugar Content and Yield

The lines used in the experiment showed wide variation in sucrose percentage and in yielding ability (Table 3). The differences between lines were maintained when seed of any size was planted. The male-sterile hybrids showed higher yield than inbred lines, irrespective of size. High sucrose percentage in male-sterile monogerm homozygous beets also did not change whether they were planted with large or small seed. Thus, even large alterations in the size of seed could not change the differences in sugar content and yield caused by genotypes of different inbred lines and male-sterile hybrids. Therefore, only small alterations in utilitarian characters caused by the different sizes of fruits can be expected.

Conclusions

The weight of germs in monogerm beets varies in proportion to the weight of fruits. Variation in sucrose percentage and in tonnage caused by different sizes of seed did not exceed the difference between inbreds which were of high and low sugar stock. Lines of different types (for example, high or low sugar) maintained their type but showed no significant difference as to planting with different seed sizes.

Breeding work for quality of seed is necessary. Monogerm varieties having small seed will be of little value. In other experiments, we observed that lines with smaller fruits gave thinner stands than lines selected for large fruits.

Significance of the size of fruits (germs) interested many investigators studying the problem of heterosis. The enormous amount of literature dedicated to this subject can not be analyzed here, but it can be noted that the point of view of Ashby (1)[2], that the high initial weight of hybrid germs gives an advantage to hybrids because they do not differ from the parents in the rate of growth, was not recognized. The opinion of East (2) is acknowledged, that the larger size seed (germ) gives the advantage to an

Table 3.—Sucrose Percentage and Yield for Monogerm Inbred Lines and for Male-Sterile Hybrids Planted of Different Size Seed.

	Location	Number of replications	Sucrose percent			Average weight of one root in pounds			Number of plants per plot			Tons per acre		
			Large Seed	Medium Seed	Small Seed	Large Seed	Medium Seed	Small Seed	Large Seed	Medium Seed	Small Seed	Large Seed	Medium Seed	Small Seed
Estimation of all inbred lines and male-sterile hybrids	Twin Falls	18	17.24	17.00	17.21	3.01	2.78	2.67	71.7	83.8	86.2	21.57	24.48	23.13
Estimation of all inbred lines and male-sterile hybrids	Salt Lake City	15	15.90	15.78	16.14	2.26	2.15	2.06	61.0	72.4	71.8	20.70	23.30	22.00
Estimation of high-sugar inbred lines	Twin Falls and Salt Lake City	9	17.43	17.23	17.13	2.15	1.95	1.88	67.0	77.7	84.7	16.23	19.60	18.08
Estimation of inbred with intermediate sugar content	do.	9	16.73	16.48	16.82	2.76	2.59	2.52	72.3	85.0	81.0	22.03	24.87	23.03
Estimation of low-sugar inbred lines	do.	6	15.84	15.84	16.25	2.62	2.56	2.39	59.0	77.5	75.0	18.25	22.40	19.65
Estimation of male-sterile hybrids	do.	6	15.85	16.00	16.23	3.62	3.32	3.25	68.5	77.5	84.0	30.00	31.15	32.90

individual only when all other conditions are equal. Size of seed can be one of the manifestations of heterosis or it can be a consequence of some other causes.

More and more interest is being manifest toward the genetic and physiological investigation of the early stages of development (5). The significance of the size of monogerm seed in the development of varieties and hybrids with high productiveness can be made clear in experiments where ontogenesis of the main beet characters may be studied simultaneously by geneticists and physiologists. The significance of the large monogerm seed must also be studied in agronomic tests by the application of a precision method of planting.

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Some Factors that Affect the Respiration Rate of Sugar Beets

MYRON STOUT[1]

Temperature

Temperature probably affects the respiration rate of sugar beets more than any other environmental factor. Average values obtained by several investigators (1) (3) (4)[2] indicate that the respiration rate is approximately doubled for each 15° F. increase in temperature. Beets grown in a cool environment also respire more rapidly than similar beets grown in a warmer environment and tested at a uniform temperature. This cool-temperature carry-over effect on respiration rate is lost when the beets are stored for a few weeks at room temperature. The respiration rate appears to be correlated with the rise and fall of thermal induction of reproductive development (5).

Carbon Dioxide Concentration

When sugar or other carbohydrates are used up in the aerobic respiration process, the molecular quantities of O_2 and CO_2 involved should be 1:1 or a respiratory quotient (RQ = 1.00). Several tests, however, have shown that CO_2 is soluble in sugar-beet tissue and may thereby indicate a false respiratory quotient value. The CO_2 retained by the beets also reduces the oxygen uptake. In one test, beets were sealed in a 55-gallon drum fitted with a small electric fan to circulate the air inside the drum before analyses were made for O_2 and CO_2 content of the storage atmosphere. The temperature was held at 21° C. Less CO_2 was given off than O_2 was taken up by the beets, resulting in a CO_2 deficit of 1.6 percent fifty-six hours after the test was started. After seventy hours from the start of the test, the beets were removed, the drum quickly flushed with air and the beets were again sealed in the drum. The data in Figure 1 show that within about two hours 1.5 percent more CO_2 was released than oxygen was absorbed by the beets. Sixteen hours after the beets were aired out and resealed in the drum, the 1.6 percent CO_2 deficit in the first part of the test

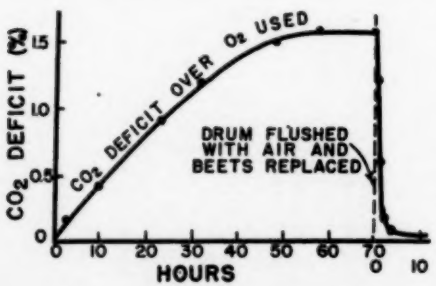

Figure 1.—CO_2 is soluble in sugar beet tissues when its concentration in the storage atmosphere is increased. This absorbed CO_2 is rapidly given off when the concentration is reduced.

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[2] Numbers in parentheses refer to literature cited.

was restored, indicating a true respiratory quotient of unity. At lower temperatures, the apparent respiratory quotient was even lower. Another lot of beets held at 16° C. removed oxygen and added CO_2 to the storage atmosphere at the rate of 0.522 percent and 0.306 percent, respectively, for 30 hours. The apparent respiratory quotient was only 0.587. The beets were placed in baskets and covered with wet burlap for 24 hours and resealed in the drum. The storage atmosphere was then enriched with CO_2 up to a concentration of 12 percent. Within six hours, the CO_2 concentration was reduced to 9.8 percent although 2.7 percent of oxygen had been absorbed during this time. At the end of 30 hours, the CO_2 concentration was 15.7 percent and the O_2 concentration had been reduced by 13.0 percent. The rate of O_2 uptake was only 0.433 percent per hour as compared to the initial rate of 0.522 percent per hour. The over-all increase in CO_2 percent was only 0.123 percent per hour as compared to the initial rate of 0.306 percent per hour. Evidently, 12 percent of CO_2 in the storage atmosphere reduced the oxygen uptake by 0.089 percent per hour, or 17 percent.

Another test showed that even small concentrations of CO_2 reduced the respiration rate. Duplicate sets of drums containing similar weights of beets were ventilated with air at three carefully controlled rates. The first pair allowed the CO_2 to increase to only 0.25 percent. The second pair allowed the CO_2 to increase to 1.69 percent and the third pair were ventilated still more slowly so that the CO_2 increased to 5.05 percent. After equilibrium had been established for several days, the respiration rates were found to be 13.52, 12.81 and 12.28 milligrams of CO_2 per kg. of beets per hour for the 0.25, 1.69 and 5.05 percent CO_2 atmospheres, respectively. The data are shown in Figure 2.

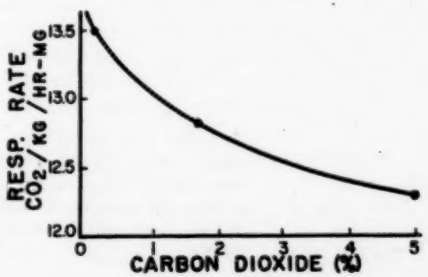

Figure 2.—Even small amounts of CO_2 reduce the respiration rate of sugar beets.

Oxygen Concentration

Two series of tests were conducted in which the storage atmospheres were free of CO_2 but the oxygen concentration was varied between 1.65 percent and 35.3 percent. The beets were different in the two separate tests and, therefore, the respiration rates at normal oxygen concentration were different. The data in one test were all corrected percentage-wise to

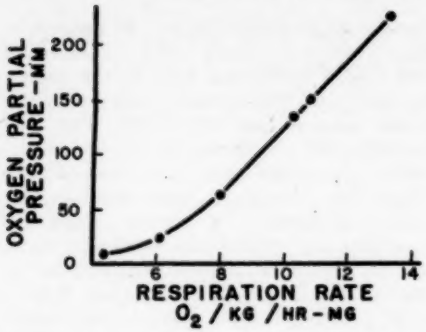

Figure 3.—The relationship between respiration rate of beets and O_2 concentration is apparently linear down to about 5 percent O_2.

correspond to the relative rate of the other test at normal oxygen concentration. The data in Figure 3 then showed a linear relationship between O_2 concentration or partial pressure and respiration rate down to a concentration of about 4 percent to 5 percent oxygen. Below this point, some anaerobic respiration apparently occurred. The beets held at the lower O_2 concentrations for several weeks also spoiled more rapidly than those above 10 percent O_2.

Size of Beet or Cut Tissue

The respiration rates of beets of the same variety but differing in average weight from about 0.7 to nearly 5.0 pounds each were determined. Each sample consisted of 40 kilograms of beets and measurements were made over a period of weeks. The data in Figure 4 show that large beets respired more slowly than an equal weight of small beets. The rate appears to be correlated with the surface area per unit of weight. Small or thin slices of tissue (2) also respire more rapidly than larger pieces (6). These facts appear to be due to reduced gaseous exchange in the interior cells of larger beets or pieces of tissue.

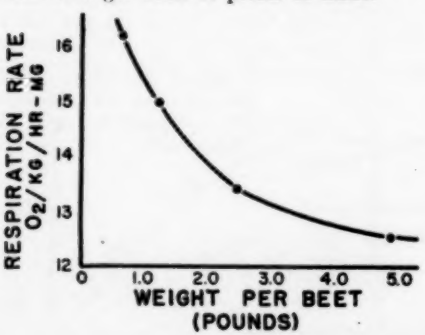

Figure 4. — Small beets respire more rapidly than large beets. The rate appears to be correlated with surface area per unit of weight.

Preliminary Study of Weight and Chemical Analysis of Individual Beets with Respiration Rate

A study of respiration, weight, sugar, amino nitrogen, sodium, and potassium on an individual beet basis between several commercial varieties, inbreds, tetraploids, mangels, and red beets indicated a negative but probably insignificant correlation between weight and respiration when the beets

were tested for respiration by the 10-gram piece technique (6). With whole beets, as shown above, the correlation was very definitely negative. The lack of definite correlation when using the 10-gram piece technique makes this method much more desirable for selection purposes. In this study respiration rate was positively correlated with sugar percentage, although not highly significant. Respiration rate was not definitely correlated with amino N content although the mean r value was slightly positive. Respiration rate was negatively correlated with sodium content. Respiration rate was not significantly correlated with potassium content. Further studies in progress should yield more definite values for these and other relationships.

Normal Diploid vs. Polyploid Sugar Beets

Polyploid sugar beets have been included in respiration rate studies for four years. In each case, the polyploids respired more slowly than normal diploid varieties tested at the same time. The average values for three years showed the polyploids respired only about 84.3 percent as rapidly as variety SL 824 tested at the same time. The average respiration rate of the four polyploids tested in 1953 was only 68.5 percent of the average rate of the two inbred diploid varieties tested under similar conditions. It seems probable that an increased cell size of the polyploids may be responsible and that the increase in cell size is greater than the increase in respiration rate per cell.

A respiration test was run comparing the respiration rates, quality and spoilage losses, of two $4n$ and two $2n$ varieties. The tetraploid of SL 824 was about 2 percent lower in sugar percentage than the SL 824 diploid. The tetraploid, however, had a significantly lower respiration rate and the total losses from respiration and spoilage were lower in the tetraploid. The tetraploid of US 22/2 was even lower in respiration rate. Previous comparisons between SL 824 and US 22/3 showed US 22/3 (a curly-top selection from US 22/2) was lower in respiration rate than SL 824. US 56/2 showed a higher respiration rate than SL 824. The data in Table 1 involved eight 44-pound analytical samples in four respiration drums for each variety. Statistical analysis showed differences as small as only 0.73 milligrams of CO_2 per kilogram per hour were significant.

Another test run in 1953 involved the curly-top resistant CT9, its male-sterile equivalent, SL 798 $4n$ (selected from US 22/2), two selections from SL 798 $4n$ (SL 241 $4n$ and SL 241A $4n$), and a $3n$ hybrid between selected stock from SL 798 and selected stock from a male-sterile CT9 hybrid SL 9090H4.

The female parent of the $3n$ hybrid, SL 241H14, was the CT9 MS hybrid SL 9090H4. SL 9090H4 combined high quality with a very high degree of resistance to inversion or spoilage during previous tests. The $3n$ hybrid SL 241H14 proved to be a very vigorous, fair-quality beet with a low respiration rate. No acre-yield rates were determined but the average weight of the $3n$ hybrid was about 300 grams heavier than that of SL 798. Small beets of the $3n$ hybrid SL 241H14, therefore, had to be selected for the samples reported in Table 2, in order to keep the size distribution of all varieties constant. This was also true of SL 241 $4n$.

The increase in reducing sugar of all polyploid beets was rather disappointing. In previous tests, a rise in the apparent respiration rate toward

Table 1.—Comparison of Quality, Respiration, and Spoilage Losses of 2*n* and 4*n* Varieties During 54 Days at 70° F., 1952

Variety	Dry sub.	Direct pol.	Purity	Amino N	Na	Invert sugar	Resp. Rate		Calculated losses, 54 days at 70° F. Sugar per ton per day			
							0_2/kg/hr	% of ave. 2*n*	Resp.	Spoilage	Total[1]	By Anal.
	%	%	%	%	p.p.m.	%	mg.	%	Lbs.	Lbs.	Lbs.	Lbs.
4*n* of SL 823	15.70	14.18	90.36	0.248	517.	0.08	8.54	89.5				
Loss	+0.48	—0.18	—3.84	+0.033	—128.	+0.50			0.365	0.185	0.550	0.067
4*n* of US 22/2	16.59	14.90	89.85	0.238	591.	0.08	7.94	83.2				
Loss	—0.08	—0.60	—3.28	+0.108	—65.	+0.45			0.339	0.167	0.506	0.222
SL 824	17.76	16.16	90.98	0.211	408.	0.08	9.55	100.0				
Loss	—0.30	—1.08	—4.63	+0.114	—94.	+0.54			0.408	0.200	0.608	0.400
US 56/2	16.30	14.53	87.86	0.204	1048	0.08	10.28	107.7				
Loss	—1.04	—1.83	—6.01	+0.080	+59	+0.67			0.440	0.248	0.688	0.680
Difference for significance					5%		0.73		0.031			
Difference for significance					1%		1.04		0.044			

[1] Sum of respiration and spoilage losses.

Table 2.—Comparison of Quality, Respiration, and Spoilage Losses of 4*n*, 4*n* Selections and 3*n* Hybrids During 52 Days at 70° F. 1953.

Variety	Dry sub.	Direct pol.	Purity	Amino N	Na	Invert Sugar	Resp. Rate		Calculated losses, 52 days at 70° F. Sugar per ton per day			
							0_2/kg/hr	% of ave. 2*n*	Resp.	Spoilage	Total[1]	By Anal.
	%	%	%	%	p.p.m.	%	mg.	%	Lbs.	Lbs.	Lbs.	Lbs.
MS of CT9 2*n*	17.70	15.51	87.58	0.240	304	0.053	10.03	96.2				
Loss	—1.43	—1.26	+0.01	+0.020	+70	+0.162			0.420	0.062	0.482	0.485
CT9 2*n*	18.37	15.98	87.64	0.230	246	0.057	10.83	103.8				
Loss	—2.48	—2.70	—4.10	+0.090	+153	+0.427			0.453	0.164	0.617	1.039
241H14 3*n*	17.16	15.15	88.34	0.206	342	0.058	7.71	73.8				
Loss	—1.04	—1.68	—4.98	+0.080	+50	+0.562			0.329	0.216	0.545	0.647
798 4*n*	17.03	15.00	88.17	0.202	336	0.052	6.90	66.0				
Loss	—0.58	—0.94	—2.75	+0.080	+49	+0.447			0.295	0.172	0.467	0.361
241 4*n*	17.94	15.46	86.13	0.156	527	0.056	7.42	71.0				
Loss	—2.02	—2.20	—2.80	+0.130	+117	+0.756			0.317	0.291	0.608	0.847
241A 4*n*	18.66	15.75	84.46	0.245	261	0.067	6.61	63.2				
Loss	—1.14	—1.97	—0.09	+0.120	+76	+0.648			0.282	0.249	0.531	0.758

[1] Sum of respiration and spoilage losses.

the end of the test, and obvious spoilage when the drums are opened, were well correlated with the increased reducing sugar in the stored beets. This was not the case in the present test. The average late increase in apparent respiration rate of the polyploids was smaller and obvious spoilage appeared to be less than in the diploid varieties in nearly all samples. Samples of polyploid beets that appeared to be in almost perfect condition had fairly large increases in invert sugar. Although 4*n* varieties have been included in several similar tests previously without any indication of unusual increases in invert sugar, the fact that practically all 4*n* or 3*n* samples in this test indicated fairly large increases warrants further study. The male-sterile equivalent (E_5) of CT9 (obtained after five successive backcrosses) appears to have higher sugar percentage, more vigor, a lower respiration rate, and greater resistance to spoilage than the CT9 itself.

Summary

Carbon dioxide in the atmosphere in which sugar beets are stored causes the beets to retain some CO_2 in the tissues. The beets give off the CO_2 rapidly when moved to a storage atmosphere containing less CO_2. Increased amounts of CO_2 in the tissues lower the respiration rate.

There is apparently a linear relationship between the respiration rate of beets and the oxygen concentration of the storage atmosphere between about 5 and 35 percent O_2. Below about 4 or 5 percent O_2, some anaerobic aerobic respiration occurs.

Large sugar beets or pieces of tissue have a lower respiration rate than smaller beets or smaller pieces of tissue. The rate is apparently correlated with surface area per unit of weight.

Polyploid sugar beets respire more slowly than normal diploid varieties. Inversion losses in polyploid varieties tested in 1953 were unusually high without apparent spoilage. This observation should be checked using the same and other polyploids.

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A Method for Determining Respiration Rate and Sampling for Chemical Analysis of Individual Sugar Beets

MYRON STOUT

Introduction

Improvements in methods of handling and storing sugar beets have been rapid during the past decade. The mechanical harvester has brought about direct delivery of the crop after lifting, thereby eliminating exposure of the beets to frost, sun and wind before piling. This, plus greater use of forced ventilation of storage piles, has done much to reduce storage losses by providing a better storage environment within the pile. Further improvement seems to be divided into two separate approaches: 1. improvements in harvester and piler efficiency and more effective control of the environment within the pile and on its surface exposures; 2. improvement of the beet itself, to reduce respiration rate and susceptibility to attack by fungi.

The first approach can be best accomplished by engineers, machinery manufacturers and agricultural departments of the sugar companies who design, make and use or supervise the use of the equipment and have direct control over the large and expensive installations.

The second approach of improving the beet itself has been studied very little in modern breeding methods. The old method, used by all sugar-beet breeders, of selecting superior mother beets or stecklings in the fall, storing until the following spring and replanting them for seed production, has eliminated most lines or individuals that were extremely susceptible to attack by fungi. This has greatly improved the sugar beet for resistance to spoilage, but individual differences are still evident within commercial varieties and some inbred lines are extremely susceptible to spoilage. Gaskill (1)[2] has shown by progeny tests that greater resistance to attack by certain fungi can be bred into lines of beets.

Very little work has been done to breed beets for low respiration rate. This has been partly due to the lack of a rapid method of sampling and conducting respiration rate measurements, as well as chemical analyses on an individual beet basis without impairing the subsequent growth of the beet. Nelson and Oldemeyer (2) reported respiration rate studies on sliced pieces of uniform thickness from the tail section of the beet. Respiration rates of these slices, ranged from about 150 to 300 mg. of CO_2 per kg. of beets per hour at 20° C. The present report describes a sampling technique, a method of measuring respiration rate, and preparation of diffusate for chemical analysis without undue injury of the beet for subsequent growth. This method is patterned somewhat after that described by Nelson and Oldemeyer, except that the sample is in the form of a cylinder. The respiration rates on the samples here reported are only about ⅓ that of the sliced tissue samples used by Nelson and Oldemeyer due to the reduced surface area of the samples.

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[1] Physiologist, Field Crops Research Branch, Agricultural Research Service, U. S. Department of Agriculture.

[2] Numbers in parentheses refer to literature cited.

The wide variations between individual beets within commercial varieties probably result from both heredity and cultural environment. Most commercial varieties can be considered as a mixture of related types because of the strong tendency of the beet to cross fertilize in the seed field. Sugar beets are also highly competitive plants with regard to space allotted in the field. A small delay in germination or early development causes a large difference in growth. The magnitude of these differences, both genetic and environmental, can be seen by the mean average values of twenty-five beets of each of twelve varieties grown on plots of equal size under normal competitive environment. Most beets smaller than 600 grams were discarded. Average values for all varieties followed by the average percentage difference or variation between the highest and lowest individuals of each variety were observed to be: weight, 1050 grams, variation 224 percent; sugar percentage 14.22, variation 61 percent; respiration rate 73.3 mg. CO_2/kg/hr., variation 83 percent; amino nitrogen as glutamine percent 0.42, variation 553 percent; sodium 800 ppm. variation 308 percent and potassium 4313 ppm., variation 81 percent. Because of these wide variations, effective selection within a heterogenous population is possible, but it requires that a large number of individuals, grown under normal field competition, be tested and only the best saved for further breeding work. Progeny tests made possible by utilizing special self-fertile types of beets permit still further genetic control.

Sampling Equipment and Technique

The most rapid and convenient test for quality of sugar beets is that for soluble dry substance by means of the Abbe refractometer. The usual procedure has been to drill a hole in the beet and press a drop of juice from the macerated tissue through muslin cloth on the prism of the refractometer. The dry substance percentage is read directly on the special scale of the instrument.

A new conically shaped tip, shown in figure 1, allows the juice to be pressed from the macerated tissue while still within the beet and caught in a plastic spoon for transfer to the refractometer prism. The tip does not penetrate as deeply as the drills which have been previously used, no cloth filter is necessary and sampling requires much less time. After a little experience, six people have tested more than 250 beets per hour. This included cleaning one side of the beet, sampling, reading dry substance and recording the values on both beet and paper, as well as numbering and selecting the choice beets. Cleaning the beets proved to be the bottle-neck of the operation. If the beets are washed previously, the testing can be speeded up with one less person, the laboratory is kept cleaner, and there is less damage to the refractometer prism. Probably 50 to 70 percent of the beets of poorer quality should be eliminated by this rapid and simple test. The remaining beets are saved for further tests. From each of the selected beets, a smooth, cylindrical piece of tissue is then cut, by means of the apparatus shown in figure 2, by placing the small hole in the beet made by the dry substance sampling tip, over a small faucet washer on the rubber anvil and forcing the handle down and quickly withdrawing it. An adjustable stop is provided for the handle to prevent the cutting tube from being damaged by severe contact with the rubber anvil. The stationary guide inside the cutter tube guides the cutter tube through the

beet and also forces the cut cylinder from the tube as the handle is raised. The cut cylinder is then easily pushed from the beet.

A piece of tissue, slightly in excess of 10 grams, is cut from the cylinder of tissue by the double-bladed instrument shown in figure 2. The remainder

Figure 1.—Improved juice extractor for use with Abbe refractometer. A ¼-inch brass brazing rod made cone-shaped and split with hack saw. Two washers forced on as shown and a piece of hack saw blade soldered in place. The blade is ground slightly lower on the "cutting side" to insure maceration rather than cutting of tissue. Second washer prevents juice draining into chuck of drill. The drill should be operated in a tilted position at about 200 to 400 r.p.m. The beet is drilled to within about ¼-inch of the first washer; then with the drill stopped further pressure expresses the juice which is caught in a plastic spoon.

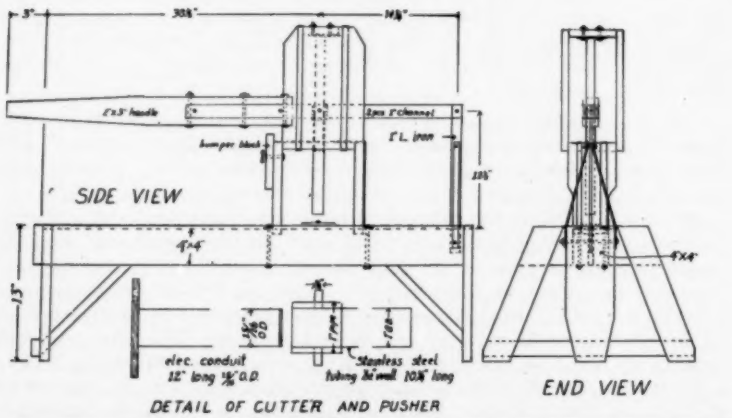
SIDE VIEW
END VIEW
DETAIL OF CUTTER AND PUSHER
elec. conduit
12" long ½" O.D.
Stainless steel
tubing .36" wall .104" long
KNIFE AND ADJUSTABLE GAUGE CUTS 26 GMS. PLUS
DOUBLE KNIFE CUTS 10 GMS. PLUS

Figure 2.—Apparatus to cut cylinder of tissue from beet. The cutting tube is forced through the beet and quickly withdrawn. This gives a remarkably clean cylinder of tissue with little effort. (See text for details).

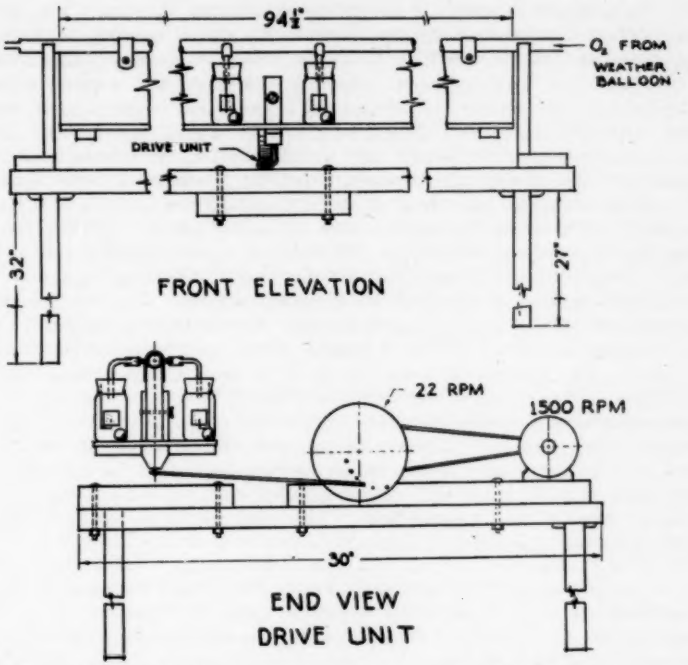

Figure 3.—Respiration apparatus. (See text for details)

of the cylinder can be placed in the groove of the single knife instrument, shown in figure 2, and a piece slightly more than 26 grams cut off. The two pieces of tissue are lightly impaled on stainless steel wires protruding from trays which hold the samples in numerical order. Three people can weigh, number, record, and sample 56 beets in about 30 minutes. The two samples are protected from undue loss of moisture until they are adjusted to weight for respiration rate measurement or disintegration for chemical analysis, as described later.

The cylinders of tissue may also be used for study of the vascular ring structure of the beets.

Measurement of Respiration Rate

The samples cut by the double-bladed knife are adjusted to 10 grams and lightly impaled on stainless steel wires soldered to a stainless steel tray, and washed with water at 45° C. (3 changes of water during 3 minutes). They are then washed in water at the temperature of the respiration measurement (usually 20° C.) for 15 minutes, blotted with a towel and stored in a closed humid chamber for three hours before the respiration test is started. (The periods and temperatures given are probably not critical but have given good results. Any procedure adopted should be consistently followed.)

The respiration apparatus shown in figure 3 has 58 units. Two units are reserved for checks (without tissue). Each unit consists of a wide-mouthed bottle 3½ inches high by 2 inches, outside diameter, closed with a No. 9 one-hole rubber stopper. The stopper is fitted with a piece of bent stainless steel wire to hold the tissue, and is connected to the oxygen manifold through semi-capillary glass tubing, rubber tubing, and a small piece of copper tubing soldered into the ½-inch pipe. The oxygen manifold is fastened to a one-inch by 4½-inch board that extends the full length of the tilting platform. The base of the tilting platform is made of ⅛-inch masonite and extends 3½ inches on each side of the center supporting board. The base is reinforced with ½ x 1½ inch slats spaced about 2 feet apart. The tilting platform is supported by the oxygen manifold pipe that fits into saddle bearings at each end of the tilting platform. The lever arm that operates the tilting platform extends below its base and is operated by a ⅛-inch steel rod connected to a wooden wheel on a small speed-reducing gearbox. The gearbox is v-belt driven by a small electric motor (about 1/10 h.p.). The gearbox and motor assembly is bolted to the supporting platform through slotted holes to provide for easy adjustment to obtain uniform tilting of the platform. Adjustment of the amplitude of tilt is made by having a series of holes in the wooden wheel on the gearbox through which the connecting rod is inserted. The unit described is operated at about 22 cycles per minute. This rate can be varied by changing pulleys on the gearbox and motor.

The tilting platform is about 94½ inches long and about 5 inches higher on one end than the other to prevent "dead centering" of the marbles on one side of the bottles. Marbles ¾ inch in diameter keep rolling much better than smaller ones.

In operation, several tissue samples are placed on the stainless steel-L-shaped supports that extend through the rubber stoppers, 5 ml. of .35 *N* $Ba(OH)_2$ are added to each bottle containing a marble and immediately fitted to the rubber stopper so that the connection is tight and the bottle rests level on the tilting platform. After all samples are in place, a weather balloon, loosely filled with pure oxygen, is connected to the manifold. The opposite end of the manifold is left open. A lighted match or cigarette held by the open end indicates when all the air is swept from the manifold. The manifold is closed and the operation started. Twenty hours after the first samples are placed in position, the apparatus is stopped and the excess $Ba(OH)_2$ in each bottle is titrated with 0.11 *N* HCl using phenolphthalein indicator. The respiration rate is then calculated by simply subtracting the ml. of HCl used for each sample from the ml. of HCl used for the "check" samples (containing no tissue) and multiplying by ten. The respiration rate is recorded as milligrams CO_2 per kilogram of beets per hour. These values are about 5.5 times the rate of respiration of whole beets averaging 1 kg. each.

Duplicate samples taken from opposite sides of the same beets and treated according to the method outlined occasionally vary as much as 10 percent. Unwashed samples were less consistent. Correlation coefficients between duplicate washed samples usually ranged between r = .85 and

r = .95. Unwashed samples sometimes gave values as low as r = .70. Respiratory enzymes in the cut surfaces or sugar that might interfere with gaseous exchange in the surface, may be responsible for the less consistent results with unwashed samples.

Chemical Analysis

A weighed 26-gram piece of the cut cylinder of tissue is sliced into a Waring Blendor equipped with well-sharpened knives, 177 ml. of distilled water added, and the machine run for only one minute and the mixture poured into a monel metal sugar cup. About 0.7 grams of Dr. Horne's dry lead acetate (dibasic) is added and the mixture shaken. After about 30 minutes, the sample is again shaken and filtered. About 18 ml. of the filtrate is saved in a plastic-stoppered, 20-ml. bottle for amino N, sodium and potassium determinations and the remainder is used for sugar determination by polarization.

Amino Nitrogen as Glutamine

Ten ml. of the clear filtrate is pipetted into a 25-ml. test tube and 1 ml. of Stanek-Pavlas (3) reagent (10 gms. $Cu(NO_3)_2.3H_2O$ plus 250 gms. $NaC_2H_3O_2.3H_2O$ per liter) added. (Better results were obtained at high nitrogen concentrations by increasing the $Cu(NO_3)_2.3H_2O$ to 15 grams per liter.) The solutions are mixed by inverting two or three times and the percent transmittance in a standard 10-mm cell at 620mμ determined with a spectrophotometer or photo-colorimeter, using distilled water as a 100 percent transmittance reference standard. The "amino nitrogen as glutamine" percent on beets is read from a decade table, prepared from a series of standard glutamine solutions (glutamic acid can be used as a standard but is less soluble, although less expensive). Any lead carbonate that precipitates and clouds the filtrate may result in high values and should be guarded against. For this reason, all sample bottles were well filled and capped to reduce contamination with atmospheric CO_2. The determinations should be run promptly after filtration for the same reason.

Although the method outlined is not as accurate as the Kjeldahl method, it is very fast and well correlated with results for total nitrogen and soluble, non-protein nitrogen in the diffusate from fresh beets, as determined by the Kjeldahl method.

Correlation coefficients calculated on more than thirty fresh-beet samples determined by three methods in 1943, gave calculated r-values as follows:

Total N % vs. amino N as glutamine %, r = + .967
Total N % vs. soluble non-protein N %, r = + .990
Soluble non-protein N % vs. amino N as glutamine %, r = + .970

The samples analyzed varied in nitrogen content as follows:

Total N (Kjeldahl)	0.105% to 0.256%
Soluble non-protein nitrogen (Kjeldahl)	0.045% to 0.188%
Amino N as glutamine (colorimetric)	0.07% to 0.65%

The method is probably useful to indicate the relative nitrogen content of fresh beets in routine or selection work.

Sodium and Potassium

Sodium and potassium are very rapidly determined on the remainder of the sample in the 20-ml. vial by means of the flame spectrophotometer. By coating the small 5 ml. sample cups with Beckman "Desicote," practically all of the previous sample can be removed by shaking; thus speeding up the determinations.

The conversion of all spectrophotometer transmission readings to percentage or parts per million values is greatly facilitated by preparing decade tables for each kind of determination.

Decade tables may be prepared as follows: The concentration for each percentage point of transmission is carefully read from the standardization curve plotted on log log paper. This curve should be nearly a straight line. These values are then calculated to the equivalent parts per million or percentage on beets, taking into consideration the dilution factor used in making the diffusate. If half-normal diffusate is used, the factor for p.p.m. on beets will be 200/26 times the concentration of the standardizing solution. These expanded values will contain larger errors due to the expansion of the values as read from the curves, especially at the higher concentrations. Errors in reading the standard curve may be reduced by making about three overlapping curves on the same sheet of log log paper. If the log scale is repeated on each axis, one curve can represent from 10 to 1,000 p.p.m., the second from 1 to 100 p.p.m. and the third from .1 to about 7 p.p.m. in the standard solutions. Errors in the expanded values may be reduced by plotting a limited part of the data at a time on large sheets of linear cross-section paper. Values for tenths or two-tenths increments of transmission readings are filled in linearly between successive percentage transmission values.

With the aid of such a table, the transmission values can be converted to p.p.m. or percent on beets very rapidly. A standard solution should be run every five or ten determinations to insure that the atomizer burner is feeding at a constant rate.

If the transmission reading of the standard solution is in error more than one or two percent, the capillary tube of the atomizer burner should be cleaned. Slight errors may be corrected by adjusting the slit width and re-running the samples back to the previous standard.

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Some Recent Advances in the Physiology and Biochemistry of Respiration

By MYRON STOUT[1]

The chain of interdependent biochemical processes collectively referred to as respiration is one of the most universal and fundamental processes of all living matter. In spite of this fact, many students of biology give it little more than passing consideration. Most of the early work on respiration has been concerned with the over-all process in relation to rates of different plants or parts of plants and the relative amounts of CO_2 and O_2 involved. It is now generally recognized that in the aerobic respiration of plants, the respiratory quotient ($\frac{CO_2}{O_2}$ = RQ) is largely dependent on the substrate being consumed in the process (2)[2]. If the substrate is a fatty acid, the RQ is lower than unity. If the substrate is an organic acid, the RQ is greater than unity while with sugar, as is principally the case in the sugar beet, the RQ is one.

We are all most interested in the favorable balance of the over-all equation for photosynthesis vs. respiration because it is this favorable balance in plants that makes all animal life, including that of man, possible. We are interested in the genetic modifications of the internal factors that improve this favorable balance, but chiefly as they affect disease resistance, nutritional and environmental requirements and hence, yielding ability, rather than the biochemical processes themselves. This situation is probably due to the fact that only in the last few decades has enough biochemical knowledge been available to explain many of the interrelated processes involved. Advances in the last few years have been phenomenal, but many processes remain to be explained and theories proved. The over-all equation for photosynthesis and respiration in simplest terms may be written as follows:

$$12\ CO_2 + 11\ H_2O + 1{,}349{,}400\ \text{cal.} \underset{\text{Respiration}}{\overset{\text{photosynthesis}}{\rightleftharpoons}} C_{12}H_{22}O_{11} + 12\ O_2$$

carbon dioxide + water + energy — sugar + oxygen

We might refer to the above reaction as an energy hill that plants are able to traverse in both directions, but animals, however, can live only by coasting back down. In our studies of sugar beet improvement, our prime interest is in augmenting the plant's ability to climb the hill and in preventing it from slipping back. We have known for some time that plants can climb this hill and that animals and plants can coast down it. We have also known that we can apply a match to the sugar at the top of the hill and see it go down like a meteorite, but it is only comparatively recently that we have learned much about the topography of the hill or the many biochemical processes and the tools used by both plants and animals in traversing it. We know we have to supply considerable energy in the form of heat at the top to start it down and we have also learned that there

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[2] Numbers in parentheses refer to literature cited.

are many more points down the hill, if we travel it biochemically, that are actually uphill and, therefore, require another energy push to get it over the small rises on the way down.

This energy is referred to as "energy of activation" and is supplied by or lowered by the enzymes in the plant or animal (24). If we supply this energy of activation in the form of heat to a quantity of sugar and oxygen at the top of the hill, the whole mass will react almost at once and give off so much energy that any small intermediate requirements on the way down are instantly met and all we know afterward is that the sugar burned. The enzymes in the cells of all living things, on the other hand, not only take the hill a step at a time, but a molecule or two molecules at a time in the case of synthetic combinations. It is only through these peculiar biochemical agents that such a large number of interdependent chemical reactions (10) can be accomplished relatively slowly, at the low temperatures compatible with living things and still yield, or use, the energy so necessary for life.

Enzymes apparently carry on all of the energy functions of the living organism. Many coenzymes such as adenosine diphosphate (ADP), adenosine triphosphate (ATP), diphosphopyridine nucleotide (DPN) and triphosphopyridine nucleotide (TPN) have multiple phosphate groups attached to the molecule. The primary phosphate bonds release only about 2,000 to 3,000 calories per mole when broken. The second and third phosphate groups release from 12,000 to 16,000 calories per mole when broken (2, 25, 24). These high-energy or "energy-rich" phosphate-containing enzymes provide much of the energy of activation necessary to make the reaction go and thus apparently transform energy from one form to another as needed by the organism. A glow worm may convert chemical energy into light by the action of enzymes (24), the light strikes the visual purple of the eye and causes an enzymatic reaction which is transmitted to the brain by another chain of enzymatic reactions (12). If we reach down to pick up the glow worm the mechanical energy of muscular contraction (24) is furnished by chemical energy through enzyme systems. Since enzymes are so universally important, what are they like and how do they manage to do the things they do?

It is now generally believed that all enzymes are proteins and that the large majority of proteins are, or have been, parts of enzymes (25). Insofar as has been determined, most vitamins (16) and probably all nutrient elements (2, 15) necessary for life, constitute important functional parts of enzymes or conditioning agents (6, 11) necessary for their functioning. Some of the elements that are important in enzyme systems are listed in Table 1. If one wonders why growing crops require inorganic nutritional elements in the quantities they seem to do, he should look at the chemical constitution of these biochemical tools. Some enzymes may be separated by dialysis, under conditions that nearly cause denaturation of the protein, into a protein or apoenzyme part and one or more coenzymes or prosthetic parts:

$$\text{enzyme} \rightleftharpoons \underset{\text{protein}}{\text{apoenzyme}} + \underset{\text{prosthetic group}}{\text{coenzyme}}$$

Neither apoenzyme nor coenzyme will function in the absence of the other,

but when recombined some of them, not denatured in the process, regain their ability to function. The apoenzyme or protein part is made up of long chains of amino acids linked together by peptide bonds between the carbon and nitrogen atoms of adjacent amino acids. These chains are usually held in spiral or folded configurations by hydrogen or S-S bonds. Denaturation (by acids, bases, heat, detergents, etc.) causes the protein to break or lose this spiral or folded structure and become non-functional. Although only about twenty-five amino acids are known, they combine to form very large molecules. A fairly simple one, lactoglobulin or milk protein has the approximate empirical formula (7):

$$C_{1864}\ H_{3012}\ O_{576}\ N_{468}\ S_{21}$$ (molecular weight 41,820).

The apoenzyme or protein part is believed to be largely responsible for the great degree of specificity of enzymes for a particular substrate or compound. The coenzyme or prosthetic groups may be more responsible for the kind of transformation of the substrate. The coenzyme is usually more heat stable, smaller and contains the vitamin-like or metallic part of the enzyme. The atoms within the prosthetic group that are capable of forming attachments to certain atoms of the substrate are usually attached to or surrounded by atoms having vacillating chemical bonds. This is usually indicated by a number of alternate single and double bonds, and indicates a higher degree of stability of the whole group or assembly of atoms. This condition between atoms is referred to as resonance (16, 17). The greatest resonance and, hence, stability is usually shown by a closed ring structure of alternate single and double bonds. A high degree of stability of the molecule as a whole, but still having bonds free to attach to certain atoms of the substrate, is an important concept to the mode of action of enzymes. It is believed (13, 21, 14) that temporary bond attachment must be made between the enzyme and substrate on opposite sides of the substrate molecules or atoms to be joined or separated. As these attachments are made, rearrangements between other bonds within the enzyme molecule may occur that cause a stretching or contraction between the points of attachment to the substrate resulting in a strain at the point of rupture, or in bringing the two closer together so that they combine. Although such theories are highly speculative because it is impossible to see what actually happens between molecules or atoms, they seem to explain the behavior of enzyme systems.

Because of their peculiar reactivity, enzymes may be subject to inactivation by other atoms or groups (9, 3, 19, 16, 15). Burkholder (3) has stated that antibiotic substances are specific chemical compounds, derived from or produced by living organisms, which even in small amounts can inhibit the life processes of other organisms. Sulfanilamide has a structure partially analogous to that of para-aminobenzoic acid. Sulfanilamide blocks the para-aminobenzoic acid in the synthesis of folic acid, thereby controlling organisms that require folic acid in order to survive (16). Penicillin apparently obstructs the assimilation of glutamic acid by certain bacterial cells and streptomycin prevents the condensation of oxaloacetate in the respiratory cycle and thus blocks the metabolism of certain organisms (9, 19). Many such cases are known. Apparently the substituted atoms attach to the prosthetic group of the active enzyme, form a more stable compound, and

in effect insert "rubber teeth" into the enzyme. Anti-vitamins, anti-auxins, as well as antibiotics are receiving increased attention. The biochemical interpretation of living processes is far from complete, but many of the interrelated processes are taking definite form and it is surprising how well other pieces of information fit into the over-all pattern. We are rapidly approaching the time when a new agent may be tailor-made to fulfil a definite function such as arresting or augmenting a given biochemical process. Most of our advances to date have concerned the coenzymes or prosthetic groups of enzyme systems. However, insulin, a fairly simple protein, has been broken into two types of peptide chains and the amino acid sequence of each chain determined, but we still do not know the configuration of the whole molecule (20).

Since enzymes are so important to the processes of life, how do they come to be formed in such varied numbers and with such definite or specific functions? It has been postulated and is now generally believed (1, 5, 8, 25, 13, 26, 18) that genes are the living, self-duplicating templates that give rise to specific enzymes that in turn determine the physiology and biochemistry of the organism. The specific conformation in structure of the enzymes which also gives rise to the specific action they have on the substrate has been compared to the mechanics of lock and key or mold and casting (8) (13) (9). Studies on the nucleic acid composition of cells, chromosomes and viruses by means of radio-active, trace-elements (22) have revealed some striking similarities in composition and ability to reproduce themselves. Viruses have been referred to as "naked genes" (5).

There seems to be a very wide variation in the action of certain enzymes within and outside living tissues. The enzyme sucrase or invertase, that, in the plant, is responsible for the interconversion of sucrose to glucose and fructose seems to allow only a very small amount of the reducing sugar glucose and fructose to be present in the root of the sugar beet. Much higher concentrations of reducing sugars are present in the petioles and leaves of beets and in the stalks of sugar cane. Outside the cell the reaction proceeds to the complete hydrolysis of all of the sucrose.

Phosphorylation of sugars, (2, 25, 23). The initial breakdown of sucrose by the addition of a molecule of water and catalyzed by the enzyme sucrase or invertase yields a molecule of glucose and one of fructose. The glucose is converted to glucose-6-phosphate by means of the enzyme hexokinase, magnesium ions, and adenosine triphosphate (ATP). The ATP is converted to ADP or adenosine diphosphate in the process. Glucose-6-phosphate is then converted to fructose-6-phosphate by phosphohexoisomerase. The fructose resulting from the initial breakdown is directly converted to fructose-6-phosphate by hexokinase, magnesium ions, and ATP. Fructose-6-phosphate is converted to fructose-1,6-diphosphate by phosphohexokinase and ATP. Again ATP is reduced to ADP in the process. Fructose-1,6-diphosphate is converted to dihydroxyacetone phosphate and 3-phosphoglyceraldehyde by aldolase. The dihydroxyacetone phosphate can be converted to 3-phosphoglyceraldehyde by phosphotriose isomerace. 3-phosphoglyceraldehyde can be converted to 3-phosphoglyceric acid by a triose phosphate dehydrogenase and ADP. Iodoacetate inhibits this process. 3-phosphoglyceric acid is converted to 2-phosphoglyceric acid by phosphoglyceromutase. This

is then converted to 2-phosphopyruvic acid by enolase. Fluoride inhibits this step. 2-phosphopyruvic acid is then converted to pyruvic acid by phosphoenol transphosphorylase and ADP. This step also requires the presence of Mg^{++} and K^{+} ions. It should be observed that all of the above reactions are capable of going in the reverse direction. That is, they are equilibrium reactions and the direction is probably dependent on the needs of the plant. An excess of pyruvic acid would probably result in the synthesis of sugar. Although all of the steps involved in the above phosphorylation of sugar in alcoholic fermentation have not been demonstrated, the evidence is very strong that the processes do occur in the aerobic respiration of higher plants. Alcohol is actually produced in anaerobic respiration, and can be easily demonstrated in sugar beets.

The Krebs Cycle (2, 23, 25, 24). It is now generally agreed that the further oxidation of pyruvic acid takes place by a cyclic transformation involving many of the common organic acids found in plants. This cyclic transformation, proposed by Krebs and Johnson in 1937, has been strengthened by more recent observations.

Recent evidence indicates that pyruvate is first oxidatively decarboxylated in the presence of coenzyme A to form an intermediate compound with the coenzyme. CO_2 and 2 (H) are eliminated. The acetyl coenzyme A then condenses with oxaloacetate to form citrate (25, 24). In the presence of aconitase, citrate can lose a molecule of water and form cis-aconitate, which in turn may gain a molecule of water and form isocitric acid in the presence of the same enzyme, aconitase. These three acids evidently form an equilibrium mixture in the presence of the enzyme aconitase. In the presence of DPN and isocitric dehydrogenase to inocitrate losses 2 (H) and forms oxalosuccinate, which in turn loses CO_2 to form α-ketoglutarate in the presence of oxalosuccinic carboxylase. α-ketoglutarate is then oxidatively decorboxylated to yield succinate, CO_2 and 2 (H). Probably α-ketoglutaric dehydrogenase and co-carboxylase are both required in this step (23). Succinate is, in turn, converted to fumarate by succinic dehydrogenase. The enzyme fumarase causes the addition of a molecule of water to fumarate to form malate which in turn is converted to oxaloacetate by the elimination of 2 (H) in the presence of malic dehydrogenase, thus completing the cycle.

Table 1.—Some Nutritional Elements and Their Functions in the Biochemistry of Cells.

Element	Enzyme or Function
N	All proteins contain N.
P	ATP, ADP, TPN, FAD, many others.
S	Probably all S-S linkages in proteins.
K	Acid neutralizer—protein stabilizer, etc.
Ca	Acid neutralizer—increases fluid viscosity, cell wall firmness, bones, teeth.
Mg	Chlorophyl, carboxypeptidase, etc.
Fe	Catalase, hemiglobin, peroxidase, cytochromes, etc.
Zn	Carbonic anhydrase, etc.
Cu	Ascorbic acid oxidase, tyrosinase, etc.
Mn	Prolidase—activates many.
Co	B_{12} formation—activates many.
B	Inhibitor for many enzymes.
Mo	Xanthine oxidase—nitrogen fixation—activator.
I	Thyroxin.

The dehydrogenases require an additional enzyme or enzymes in order to unite the hydrogen with oxygen to form water. This step is referred to as terminal oxidation. In animal tissues cytochrome oxidase is apparently the enzyme responsible for this step. In higher plants two additional terminal oxidases have been recognized. Polyphenoloxidase has been found in potato tubers and spinach leaves. A nonmetal oxidase has been found in carrot leaves and avocado fruits. Cytochrome oxidase has been found in wheat embryos, pollen, and oat seedlings. Cytochrome C reductase also intervenes between cytochrome C and the codehydrogenases DPN and TPN and converts DPN into TPN by the addition of phosphate. Enzymes thus apparently work in teams (10).

Summary

Advances in the biochemistry and physiology of living cells have been very rapid during the past few years. This review article is an attempt to describe to those not necessarily closely following the subject, some of these advances as they apply to the respiration process. The literature cited was selected principally from review articles that are easily understood and contain a minimum of technical details. The chemical constitution of the "tools," the enzymes of the cells or organisms affords a better understanding of nutritional requirements.

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The Nutrition of Cattle and Sheep

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The nutrition of cattle and sheep differs from that of swine and poultry because of the rumen. The rumen has large capacity and is used as a storage place for large quantities of forages and the so-called roughages. Partly because of this ability to store large amounts of feeds, the ruminants are excellent grazing animals. The rumen also is the location of a special type of digestion. It is in the rumen that various microorganisms live and grow and in the process, break down certain chemical compounds in the feed into forms that can be utilized by the animal. The microorganisms also build up from simple ammonium compounds the complex proteins which can be used by cattle and sheep to partially meet their nutritive requirements.

The feed is subjected to a thorough mixing, maceration, and fermentation in the rumen while awaiting rumination. At intervals, portions are returned to the mouth for remastication and a second mixing with saliva. The reswallowed food returns to the rumen and the extensive chemical digestive changes continue. These digestive changes are caused by plant enzymes or microorganisms or both, since the saliva contains no ptyalin and there is no secretion of digestive juices into the rumen. The digestion of cellulose is a good example of this action. Cellulose is the chief constituent of crude fiber. It is generally believed that bacteria are the main agents in this digestive process. In any event, it is necessary that all of the nutrients required by the microorganisms be present if cellulose digestion is to be approximately complete. Perhaps this explains the varying digestibilities of feedstuffs or the same feedstuff when tested under different conditions. A number of nutrients have been shown to be essential for best ruminal digestion. Among these essentials are the minerals cobalt, calcium, magnesium, sodium, potassium, iron, phosphorus, chlorine, sulfur, and possibly others such as copper, iodine, zinc, and manganese.

Molasses, yeast, distillers grains with solubles, soybean meal, linseed meal, and alfalfa also have been reported to stimulate cellulose digestion. It is of interest to note the ash of alfalfa and molasses also improve cellulose digestion in the rumen. On the other hand, too much readily available carbohydrate has an inhibiting effect. These various factors must be considered in the selection of the optimal supplement or ration.

If the ingesta in the rumen is, or approaches, the ideal substrate for the microorganisms, the simple compounds of nitrogen can be built up into the proteins which comprise the body of the microorganism. After these cells die, they are digested by the animal and are utilized in the same manner as the proteins of the feedstuff. A number of nitrogenous compounds have been studied, but most of the work has been done with urea. The literature dealing with the feeding of urea is large and in general there is agreement as to the best methods of its use in feeds. Recently, a new

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product has been produced by reacting ammonia with molasses. This product is called ammoniated molasses and feeding tests indicate that it is a satisfactory source of nitrogen for ruminants. Urea does not supply energy to the ration; therefore, it must be supplemented with carbohydrates or carbohydrate rich feedstuffs. In the case of ammoniated molasses, the molasses supplies a part of the needed energy in addition to nitrogen. At present, it is recommended that not to exceed one-third of the protein be supplied by urea or other non-protein forms of nitrogen. With proper precautions, a somewhat higher level may be used without producing a toxic effect. Overfeeding with urea is definitely dangerous.

In this connection, the by-products of the sugar industry should be mentioned. The feeding of beet pulp both wet and dry is well known. Nutritionally, beet pulp is low in protein and fat and high in fiber. However, the fiber in beet pulp is well digested by ruminants and is well utilized by both cattle and sheep. Another by-product is molasses which is a rich carbohydrate feedstuff. Because of the difficulty in handling molasses, it is often mixed with a carrier. Some materials have been used as carriers which have very little feeding value. The livestock man wants a feed that has a high feeding value and supplies the nutrients needed to supplement his forage. Therefore, does it not seem logical that nitrogen be added by ammoniating molasses or some other product which research will develop? Then mix the molasses with a carrier of high nutritive value and other nutrients to form a high grade feed supplement based on by-products.

Much of the time, the feed consumed by cattle and sheep is far from ideal. For example, young, rapidly growing grass has a high protein content and a low crude fiber. Such grass is readily digested and supplies many important nutrients. However, as the plant matures the protein decreases, the fiber increases, and the digestibility falls markedly. Chemical analysis of grass at this stage shows that the lignin content is increasing rapidly. Lignin is indigestible and cannot be utilized by livestock. It also interferes with the digestion of the other nutrients and decreases the feeding value of the grass. There are different theories as to the mode of action of lignin in inhibiting digestion. One is that lignin encases the other compounds and prevents the digestive juices from coming into contact with them. Another is that there is a chemical bond between lignin and other constituents of the plant. Recent histological studies indicate that the position of lignin in the plant is of great importance in its effect on nutritive value. It has been observed that in grasses that maintain their nutritive value as they mature, the lignin is confined to the vascular bundles, while in grasses that lose their nutritive value rapidly as they mature, the lignin is not only present in the vascular bundles but in the surrounding tissues as well. Much more experimental work is needed in this field, especially now that the emphasis is on making the maximum use of forage and roughage in cattle and sheep production.

There is another important factor in nutrition that cannot be determined by chemical nor physical analyses. That is palatability. It does not matter how much digestible protein or total digestible nutrients a feed contains if the animal will not eat it. It is possible to increase the palat-

ability of coarse hay or straw by sprinkling it with molasses. In an experiment at Beltsville, the addition of a small amount of molasses increased the consumption of low-grade hay 10 percent. This small increase in consumption of hay by beef cows resulted in a consistant slight increase in body weight. It has been suggested that consumption of dry, brown grasses in the pasture could be increased by spraying them with molasses. This procedure would be feasible in locations of moderate rainfall. The best method, of course, is to grow the most palatable pastures and make the best possible hay and silage.

Formerly, a single feed or a very simple mixture was used to supplement forages. Now, much more complex supplements are recommended. Examples of these supplements are the Purdue A and the Iowa numbers 1 and 2. Each of the components of these mixtures has a function, and, while it is not definitely known what all of these functions are, some of them are obvious. The Purdue Supplement A, for example, is fed at the rate of 3.5 pounds per day with corncobs. The 2.25 pounds of soybean meal supplies protein of good quality and possibly other factors; the molasses feed which contains 0.45 pound of molasses supplies energy, minerals, and increases palatability; and the 0.18 pound of bonemeal supplies calcium, phosphorus, and other minerals. The functions of the iodized salt and vitamin A and D feeding oil are obvious. Such supplements not only supply nutrients to the animal but they furnish necessary nutrients to the microorganisms in the rumen. When the nutritive requirements of cattle and sheep, as well as those of the microorganisms in rumen are determined, it will be possible to design an ideal supplement. Then, the animals will make the best use of roughage at a minimum of cost.

In general, the nutrition of cattle and sheep is the same or at least very much alike. However, certain differences should be mentioned. It is usually more difficult to get lambs on full feed by the ordinary hand feeding method. The time can be shortened by making the entire ration into pellets, starting with a hay-grain mixture of 3 or 4 to 1 and then changing gradually until the ratio is about 1 to 3. The lambs cannot overfeed on grain, and we believe that it also speeds up the change in the microorganisms from the type that utilize roughages best to the type that is most suited for heavy grain feeding. In lamb feeding tests at Beltsville using this technique, we have been able to get average daily gains as high as 0.75 pound per day. Sheep are good grazing animals and make good use of roughages. However, sheep do not appear to be able to make as good use of the coarse hays as cattle. This fact becomes evident when rations are calculated on a TDN basis. When sheep are fed a ration which appears to contain sufficient TDN, they may not make the expected gains. This is due to the fact that they will not eat all the feed that is given them and to the fact that the productive energy of a pound of TDN of the portion that they do eat of poor roughages is considerably lower than a pound of TDN from the better roughages.

The vitamin requirements of ruminants are quite different from other classes of livestock. This is partly due to the fact that the vitamins of the B complex can be synthesized in the rumen. A combination of sunshine

and sun-cured feeds usually supply adequate amounts of vitamin D. It is vitamin A that is most likely to be deficient, especially in times of drought and under feed lot conditions. Cattle and sheep obtain vitamin A by converting carotene into vitamin A in the body. Normally, there is some storage of excess vitamin A in the animal body. This stored vitamin will prevent the development of severe deficiency symptoms for several months. The deficiency symptoms develop rapidly when the animal is placed on a vitamin A free ration following a period when little storage has taken place. The symptoms of vitamin deficiency are well known and are usually recognized in time for proper treatment. If treatment is not started in time or neglected entirely, death will ensue. Steers which are deficient in vitamin A develop a generalized edema (anasarca). Steers which are found to have this condition at slaughter are condemned. Many thousands of dollars have been lost because this disease was not recognized in time and before its cause was determined.

The blood of cattle normally contains both carotene and vitamin A while the blood of sheep contains only vitamin A. The reason for this physiological difference is not known and may result in different requirements of vitamin A. In preliminary studies with sheep at Beltsville, it appears that the requirement for sheep for reproduction is much less than for cattle. Lambs have been produced under conditions that resulted in failure with cattle.

Most of the essential minerals are supplied by the feedstuffs which are usually included in good rations. It is necessary, however, to pay particular attention to calcium and phosphorus. Rations can be balanced for energy and vitamins, for example, but fail to have a balance between calcium and phosphorus. Some feeds, like cottonseed oil meal, contain more phosphorus than calcium, while alfalfa, on the other hand, contains more calcium. Therefore, when cottonseed meal and alfalfa are fed together, the calcium and phosphorus ratio is improved. There appears to be a rather wide range of calcium and phosphorus rations which are satisfactory from a nutritional standpoint, provided that there is a sufficient amount of both elements present. There also must be an adequate amount of vitamin D present to insure the proper utilization of the calcium and phosphorus. Rickets can result from a deficiency of any one of these three factors.

Cobalt is one of the essential trace elements and has several functions. It is a part of the vitamin B_{12} molecule and, hence, it must be present in the rumen so that synthesis of this vitamin can take place. Cobalt is also involved in blood formation. Pining disease, Enzootic Marasmus, and bush sickness can be prevented by the use of cobalt either as fertilizer or as a constituent of the ration. There is not much known about the physiological action of cobalt. However, it has been shown that oral administration is much more effective than injection in restoring deficient sheep to health. Cobalt also has an effect on the numbers and kinds of microorganisms in the rumen.

Iodine is an essential of thyroxine. The total amount of iodine in the body is small; most of it is found in the thyroid gland. The metabolic rate is dependent on thyroid function, and so iodine becomes of great impor

tance. Ruminants will develop goiter if there is a deficiency in iodine, and there will be very poor reproductive results unless pregnant animals are supplied adequate amounts of iodine.

Copper appears to be essential for the conversion of iron into hemoglobin in cases of nutritional anemia. There is ample evidence that copper deficiency leads to ill health in livestock. A lack of copper is involved in the disease which is known in Florida as "salt sick" and in Australia as "coast disease." In copper deficient sheep, there is a loss of wool or a deterioration of its quality. There is loss of hair or poor pigmentation in other species. On the other hand, an excess of copper is toxic. An outstanding symptom of copper poisoning in sheep is the discoloration of mucous membranes and white parts of the skin. Death often occurs in one or two days after the development of the jaundice. Sheep can tolerate higher levels of copper if molybdenum is present.

Iron is an essential constituent of hemoglobin and is thus of fundamental importance. Green foods are usually rich in iron in a form that seems to be completely available. Milk is natural food which does not contain sufficient iron to meet requirements. This at least in part is the cause of the anemia often seen in the young. Pigs are especially susceptible to this disease. There is an interrelationship among iron, copper, and cobalt in the development of nutritional anemia. These elements and other factors are involved in hemoglobin synthesis.

Zinc is found in all parts of the animal body and appears to be an essential. Rats, when deprived of zinc, show a retarded growth and a deterioration of fur. There have been no cases reported of zinc deficiency developing in cattle or sheep which were kept under natural conditions. Excessive amounts of zinc are poisonous.

Manganese is an essential in the prevention of slipped tendons in poultry. It also may be required by swine in such amounts that it should be added as a supplement. There is no evidence that more than the amount which occurs in feedstuffs is required by cattle or sheep.

Most of the magnesium in the body is found in the bones and the rest is widely distributed. Magnesium is concerned with the activation of the phosphatase enzyme and is thus indirectly connected with carbohydrate metabolism. A deficiency of magnesium produces a tetany which appears to be identical to "grass tetany." Recent work with dairy cows has set the requirement at 30 to 40 grams of magnesium per day. Severe tetany has been produced when the daily intake of magnesium was dropped to 10 grams. In all cases of tetany, there was a lowering of the blood magnesium. There was no exact correlation between the degree of hypo-magnesaemia and the magnesium intake. The facts suggest that there may be an unknown factor involved which controls the utilization of magnesium. Magnesium is involved in some cases of urinary calculi.

Sodium and potassium are found in the soft tissues and in the body fluids. Most feeds contain sufficient potassium to meet the requirements of all animals under normal feeding conditions. On the other hand, there is not enough sodium in feedstuffs and there is often a sodium chloride de-

ficiency. Chlorine is an important constituent of gastric juice as well as being an important factor in the acid-base equilibrium. The grain ration of cattle and sheep should contain from 0.5 to 1.0 percent of salt. There does not appear to be much danger from an excess of salt although cases have been reported of death due to overeating of salt after a long period of deficiency.

In addition to the elements already discussed, there are others which are always found in the body, but their essentiality has not been demonstrated. There are also some toxic elements which have no nutritional functions. The so-called "alkali disease" is due to selenium poisoning. Any soil containing 0.5 parts per million is potentially dangerous. Molybdenum is also toxic to animals and is responsible for "teartness," a disease which occurs in certain pastures in England. Fluorine is toxic and is of importance because of its close association with phosphorus. Cattle and sheep feeders must insist on defluorinated phosphates in their feed supplements. Oat hay poisoning is due to an excessively high content of potassium nitrate. The condition is most common in ruminants and is believed to be due to the conversion of nitrates to nitrites in the digestive tract.

There is one disease which is associated with nutrition that can not be classed as a deficiency disease—in fact it is just the opposite. It is sometimes called overeating disease or fat lamb disease. It is caused by toxins which are produced by organisms in the rumen. These organisms thrive under the same conditions that are conducive to good digestion and hence rapid growth in the animal. At Beltsville, we have had very good results by inoculation just before the lambs go on fattening rations.

Pregnancy disease is associated with poor nutritional management of the ewes before lambing time. It occurs when the plane of nutrition is too low or is declining at lambing time. There is no advantage in feeding grain to pregnant ewes during the first two-thirds of the gestation period. The feeding of grain during the last part of the gestation will usually result in better lambs and the ewes will give more milk. Also, this plan results in an increasing plane of nutrition just before lambing and is effective in preventing pregnancy disease.

Another troublesome disease which is associated with nutrition is grass tetany or wheat pasture poisoning. It is apparently the same disease and named from the type of pasture. Both cattle and sheep are affected. The losses from wheat pasture poisoning are often high, especially when the pasture is lush. The cause is not known, but many workers think that there is an imbalance of minerals involving calcium, magnesium, potassium, and sodium. It has been suggested that the high protein and relatively low available carbohydrate is a contributing factor. The usual treatment is intravenous injection of calcium gluconate, and if this treatment is given in time a high percentage of the animals recover. It is believed that if the animals have access to dry feed such as hay or sorghum bundles there is a lower incidence of the disease.

Urinary calculi cause heavy losses in cattle. The cause of this condition is not known, nor is there any cure. Surgical intervention often will

save the animal, but this treatment is not often given. The evidence indicates that the stones start to form in the kidneys while the animals are still on the range and develop in the feed lot. Many causes have been suggested, such as vitamin A deficiency, drinking saline water, eating plants with a high oxalate content, and many others. It is also possible that the nucleus about which the stone developes is caused by bacterial infection or the sloughing off of epithelial cells. Our experiments have indicated that the addition of bone meal to the ration is fairly effective as a preventative. The addition of limestone to the diet does more harm than good. Much more research will be required before the cause and prevention of these nutritional diseases will be known.

In conclusion, the study of ruminant nutrition covers a broad field in which there are many unsolved problems. These problems are of scientific and commerical interest. The nutritionist tries to determine the requirements for different classes of animals at the various stages of growth and development. When these requirements are determined, it is the task of the commercial man to translate this into a practical feed. Many industries have by-products which can be utilized to advantage in feeds. Therefore, they should be encouraged to engage in research which will not only benefit themselves but the livestock raiser as well. It is not enough to be able to feed for growth; feeding for health is just as important. Therefore, let us all attack these problems with all of the skills and resources at our command.

Grainless Beet By-Product Rations

W. A. HARRIS AND R. H. COTTON[1]

On Holly Sugar Corporation's experimental feedlots at Torrington, Wyoming, last year we carried four pens of cattle to slaughter on rations composed almost entirely of beet by-products. Contrary to usual practice and recommendations for feeding beet by-products (2, 5)[2], none of these rations contained grain. The purpose, was to see if a satisfactory finish could be obtained in a reasonable length of time with beet by-products and without use of grains.

Procedure

The cattle used were yearling Hereford steers all originating from one ranch in New Mexico.

Twenty steers were fed in each experimental pen. The pens were filled by random gate-cuts from the intermediate size group of a large purchase of animals. Each pen had animals ranging from 660 to 760 pounds. Average weights of the different pens varied between 694 and 710 pounds.

Individual records of gain permitted analysis for significance (4). During the month between the time of purchase and the start of the experimental feeding, the steers were on a ration of wet pulp, alfalfa, and cottonseed cake, and then were on experimental feed for 188 days—from late November to the first of June. After the final weighing of each lot was completed, it was trucked to Swift and Company in Gering, Nebraska. The steers were slaughtered the following day in the same lot sequence that they had been weighed, and individual slaughter records were kept on each steer.

Off-truck weights of each lot as delivered gave a relative picture of shrink in transit. Since individual live weights could not be made at the packing house, it was not possible to analyze these data statistically. The customary 4 percent shrink was, therefore, applied to all Torrington weights, and these shrunk weights were used in calculating net gains and dressing percentages. Animals were not sold on the open market. Payment was made on the basis of carcass grade and dressing percent and calculated back to a live weight value. These values are of interest because they combine the two determined criteria, dressing percentage and grade, and therefore, more accurately reflect the ration value than open market bids.

The packing house grader assigned numerical grade-values to each carcass, both before and after ribbing, thus permitting statistical comparison of the pens.

Daily aliquots from all feeds were combined monthly for periodic analysis, except for molasses and wet pulp which were sampled monthly. The average analyses are shown in Table 2.

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[1] Research Chemist and Director of Research, respectively. Holly Sugar Corporation. Colorado Springs, Colorado.

[2] Numbers in parentheses refer to literature cited.

Table 2—Average Analyses of Feeds.

	Dry Matter	Ash	Crude Protein	Ether Extract	Crude Fiber	Nitrogen-free Extract	Est'd. Total Dig. Nutrients	Est'd. Dig. Protein
Alfalfa	93.49	8.10	11.59	1.80	36.77	35.63	50.66	8.23
Straw	96.12	5.58	2.41	0.77	45.63	41.73	44.25	0.19
Wet pulp, 1st period	9.49	0.48	1.11	0.18	3.23	4.49	7.21	0.61
Wet pulp, 1st 4 periods	10.29	0.51	1.42	0.27	4.12	3.97	7.65	0.78
Wet pulp, last 2 periods	13.91	0.66	1.96	0.43	6.01	4.85	10.28	1.08
Mol. dried pulp	93.81	6.19	7.78	0.47	16.97	62.40	73.76	5.27
Corn	89.97	2.74	8.95	3.81	2.28	72.19	83.05	6.89
Molasses	74.01	7.18	4.78	—	—	62.05	58.96	2.49
Beet top silage	27.05	7.01	2.42	0.43	4.83	12.36	15.85	1.62
Sugapulp	93.41	9.70	8.36	0.19	8.05	67.11	71.02	5.52
43% Cottonseed cake	94.57	6.58	45.95	5.76	11.60	24.68	74.47	38.14
22% Comm. pellet	92.63	8.40	24.11	3.23	9.33	47.36	71.74	18.83

Three types of rations were used: 1. wet pulp; 2. beet-top silage (this was fed only during the first part of the experimental feeding period and was replaced with wet pulp during the last part of the feeding period); and 3. molasses dried pulp.

The first wet-pulp pen received an average of about 90 pounds of pulp, 4½ pounds of alfalfa, 3 pounds of molasses, and was supplemented with 2 pounds of 43 percent cottonseed cake. The second wet-pulp pen was fed identically except that the ration was supplemented with 3 pounds of a vitamin-fortified commercial 22 percent protein pellet instead of with cottonseed cake.

The silage pen was on a full feed of top silage within 25 days from the start of the feeding with about 80 pounds of silage, 2 pounds of dried molasses (Sugapulp), and 2 pounds of the 22 percent protein supplement. After 114 days, the ration was changed to the pulp-molasses-alfalfa ration except that only 2 pounds of the 22 percent protein supplement was fed.

The dried-pulp pen was fed nothing but 2 pounds of straw, 2 pounds of the 22 percent protein pellet, and molasses dried pulp to capacity for the entire 188 days.

The performance of these rations was compared with that of typical corn-belt rations: one grain-fed pen received 1 pound of 43 percent cottonseed cake, 7 pounds of alfalfa, and corn to capacity. A second pen was fed the same except that 1 pound of the 22 percent protein pellet was used instead of cottonseed cake.

Results and Discussion

Results are shown in Table 1.

The corn-belt pens (Nos. 1 and 2) showed a net gain of 1.96 and 2.00 pounds per head daily with the cottonseed cake and commercial supplement, respectively. The dried-pulp and wet-pulp pens all gained 1.9—a difference from the corn pens that was not statistically significant. The

Table 1.—Grainless Beet By-Product Rations.

Pen Number:	1	2	8	22			23	24
				Comm. 22% Protein Pellet				
Type of Supplement	43% Cotton-Seed Cake	Comm. 22% Protein Pellet	Comm. 22% Protein Pellet	1st 114 Days	Last 74 Days	Total	43% Cotton-Seed Cake	Comm. 22% Protein Pellet
Initial Weight, lbs.	689.5	694.0	709.8	—	—	707.3	696.5	705.3
Final Weight less 4%, lbs.	1055.1	1067.8	1067.8	—	—	1042.6	1053.4	1065.1
4th Period Wt. less 4%, lbs.	—	—	—	905.3	—	—	—	—
Net Total Gains	365.6	373.8	358.0	198.0	137.3	335.3	356.9	359.9
Net Daily Gains	1.96	2.00	1.90	1.74	1.86	1.78	1.90	1.91
Ave. Daily Feed, lbs:								
Chopped alfalfa	6.98	7.25	0.30[1]	0.56[3]	4.46	2.09	4.54	4.54
Wet pulp	3.55[3]	3.72[2]	—	10.54[4]	86.55	40.46	90.08	89.32
Molasses	—	—	—	—	3.00	1.18	2.98	2.98
Wheat straw	—	—	1.96	—	—	—	—	—
Beet top silage	—	—	—	68.62	—	41.61	—	—
Molasses dried pulp	—	—	17.66	—	—	—	—	—
Sugapulp	—	—	—	1.95	—	1.18	—	—
Corn	13.41	13.73	—	—	—	—	—	—
Supplement	0.997	0.995	1.969	1.96	2.00	1.98	1.98	2.95
Salt (free choice)	0.023	0.027	0.020	0.044	0.049	0.046	0.053	0.030
Mineral (free choice)	0.096	0.097	0.045	0.015	0.086	0.043	0.054	0.054
Ave. Feed per cwt. Gain, lbs:								
Chopped alfalfa	357.2	362.9	15.8[1]	32.2[3]	240.5	117.4	238.9	237.7
Wet pulp	181.7[3]	186.1[2]	—	605.7[4]	4666.3	2273.0	4741.1	4676.4
Molasses	—	—	—	—	161.7	67.8	156.8	156.0
Wheat straw	—	—	103.0	—	—	—	—	—
Beet top silage	—	—	—	3949.8	—	2337.6	—	—
Molasses dried pulp	—	—	927.5	—	—	—	—	—
Sugapulp	—	—	—	112.9	—	66.3	—	—
Corn	685.7	687.1	—	—	—	—	—	—
Supplement	51.0	49.8	103.4	112.9	107.8	111.2	104.2	154.5
Salt (free choice)	1.16	1.27	1.05	2.52	2.62	2.58	2.79	1.57
Mineral (free choice)	4.92	4.88	2.37	0.88	4.64	2.42	2.84	2.83

Table 1.—Continued, next page.

Table 1.—Grainless Beet By-Product Rations (Cont'd.)

Pen Number:	1	2	8	22			23	24
				Comm. 22% Protein Pellet				
Type of Supplement	43% Cotton-Seed Cake	Comm. 22% Protein Pellet	Comm. 22% Protein Pellet	1st 114 Days	Last 74 Days	Total	43% Cotton-Seed Cake	Comm. 22% Protein Pellet
Feed Cost per cwt. Gain, $	30.40	30.42	29.37	21.84	18.73	20.57	18.13	20.30
Market Value per cwt., $	22.00	21.50	22.00	—	—	20.00	20.70	21.00
Actual Shrink to Market	2.50%	1.69%	2.72%	—	—	5.75%	5.13%	4.10%
Dressing Percent	61.92%	61.33%	61.98%	—	—	57.10%	58.88%	59.51%
U. S. Grade (carcass and ribbed)								
Prime, No. of steers	0-0	0-0	0-0	0-0	0-0	0-0	0-0	0-0
High choice, No. of steers	6-6	1-0	4-6	—	—	1-1	1-4	5-3
Medium choice, No. of steers	13-13	17-16	16-14	—	—	14-13	16-14	15-17
Low choice, No. of steers	1-1	2-4	0-0	—	—	5-5	3-2	0-0
Good choice, No. of steers	0-0	0-0	0-0	—	—	0-1	0-0	0-0
Average Numerical Carcass Grade	5.75	4.85	5.60	—	—	4.40	4.70	5.75
Average Numerical Ribbed Grade	5.65	4.60	6.30	—	—	4.45	5.80	5.75
Estimated Dig. Protein, lbs.:								
Daily	1.90	1.75	1.33	1.70	1.75	1.72	2.00	1.80
Per cwt. Gain	96.9	87.5	70.0	97.7	94.1	96.6	105.3	94.2
Estimated TDN, lbs.:								
Daily	15.68	16.06	15.31	14.73	14.36	14.59	13.28	13.87
Per cwt. Gain	800.0	805.0	805.8	846.6	772.0	819.7	698.9	726.2
Estimated Nutritive Ratio 1:	7.25	8.18	10.51	7.66	7.21	7.48	5.64	6.71

LSD 5% level—rate of gain	0.16
LSD 5% level—dressing percentage	0.85
LSD 5% level—market value	0.37
LSD 5% level—numerical carcass grade	0.87
LSD 5% level—numerical ribbed grade	0.95

Average per ton price of feeds used: chopped alfalfa $36.00; wet pulp, 1st 114 days, $2.33; wet pulp, last 74 days, $2.70; molasses $30.18; chopped wheat straw $15.50; beet top silage $4.75; molasses dried pulp $49.50; Sugapulp $100.00; corn $60.49; 43% cottonseed cake $100.72; commercial 22% protein pellet $98.10; salt $16.00; mineral $180.77.

[1] Fed 12 days only
[2] Fed 13 days only
[3] Fed 20 days only
[4] Fed 25 days only

silage pen (No. 22) showed a significantly lower over-all daily gain than the corn pens. Actually, the rate of gain was slower only during the period of silage feeding. The 1.78 pounds over-all daily gain per head of this pen missed being significantly different from the 1.9 pounds daily gain of the all-pulp rations.

It should be pointed out that the silage used in this experiment was of very poor quality. Because of a severe pre-harvest freeze, tailings from the mill were combined in the silo with the over-dry tops from the field. Tailings made up more than half the total ensilage.

Gains from the wet rations cost approximately two-thirds as much as gains on the dry rations, considering only the cost of feeds. Cheapest gains were with cottonseed-supplemented wet pulp, which cost only $18.13 per hundred pounds. The all-dried pulp ration of pen No. 8 was only about $1.00 per cwt. cheaper than the $30.40 of the all-grain rations at the high pulp price used.

Pens on the wet rations shrunk more in transit than the dry ration pens, and dressed significantly lower.

No carcass graded lower than U. S. choice. However, there were notable differences within the grade that showed up in an arbitrary numerical system of grading by which the grader could assign a value of 1 to 9 for quality ranging from high-good to low-prime.

Oddly, the corn pen which was supplemented with the commercial pellet (No. 2) graded significantly lower, by this numerical system, than its companion lot that was supplemented with cottonseed cake and resulted in a significantly lower market value. The corn-cottonseed pen (No. 1) out-graded the wet pulp-cottonseed pen (No. 23) significantly but, on the other hand, the wet pulp-commercial pellet pen (No. 24) significantly out-graded the corn-commercial pellet pen (No. 2). Although the dry-pulp pen (No. 8) also out-graded the same corn pen, the difference missed being significant; however, it did have a significantly higher market value. The silage pen graded somewhat lower than any of the others, though it wasn't significantly different from pens No. 2 or 23.

After the carcasses were ribbed and the market grade of the meat evaluated by the same numerical grading system, a little different picture presented itself. Both corn pens down-graded very slightly, while all beet by-product pens either maintained their grade value or improved. After ribbing, the grade of the dry-pulp pen was raised markedly, from 5.60 to 6.30, to make it the highest grading pen of the experiment; and the up-grading of the wet pulp-cottonseed pen to 5.80 from its original low value of 4.70 was so marked, that it was ranked second. Only the silage pen and the corn-commercial supplement pen still were graded so low as to be significantly different from the other four pens.

Because the analysis of feeds was not started until near the completion of the trials, the lower-than-normal protein value of the dried pulp was not determined in time to correct the sub-normal protein level of pen No. 8. The average daily digestible protein intake of this pen was only 1.33

[illegible] Fed 20 days only
[illegible] Fed 25 days only

pounds per head, 0.3 to 0.4 pounds below the level recommended by the National Research Council (1) or by Morrison (3). This, of course, resulted in the very wide nutritive ratio of 1:10.5. Presumably, a more adequate protein intake would have resulted in still better gains for this pen.

Summary

Using 20 steers per pen, 700-pound yearling Herefords were fed for 188 days on rations of beet by-products without grain. Gains and market data were compared with those of pens on grain-belt rations. Except for the beet-top silage ration, gains were comparable. In all cases, gains were cheaper for the by-product rations. All carcasses were within U. S. choice grade. Lower dressing percentages and lower numerical carcass grades resulted in lower market value for all by-product pens except the dry-pulp pen.

Re-evaluation of numerical grade, after ribbing, showed a marked tendency for the by-product fed pens to show improvement over the original carcass evaluation. This was not true of the corn-fed pens. Although meat quality was judged rather accurately by the carcass alone on the corn-fed cattle, carcass grading did not always accurately reflect the higher quality of beet-by-product-fed cattle.

ACKNOWLEDGMENT

Thanks are due to the Colorado Milling and Elevator Company for sharing in the costs of this investigation.

We wish to thank Roy Wiand, Roger S. Smith, Louis P. Orleans, and J. Alve Cole, of Holly Sugar Corporation, and Dr. William H. Burkitt, of Colorado Milling and Elevator Company, for their help in this study.

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SOCIETY
RECORDS

Minutes of the Eighth General Meeting American Society of Sugar Beet Technologists

The business session of the Eighth General Meeting of The American Society of Sugar Beet Technologists was called to order by the Society's president, Mr. C. E. Cormany, at three p.m. on Thursday, February 4, 1954, in the Empire Room of the Shirley-Savoy Hotel, Denver, Colorado.

Mr. Cormany, presiding as chairman of the meeting, announced that this meeting had been called for the purpose of hearing committee reports, report of the secretary, report of the treasurer, and transacting what other business may be appropriate.

The chairman then called for a reading of the minutes from the Seventh General Meeting held in Salt Lake City, Utah, February 7, 1952. Upon motion by H. E. Brewbaker, seconded by J. R. Douglass, and unanimously carried, the reading of the minutes from the Seventh General Meeting was dispensed with.

The chairman then requested that the Report of the Secretary be read. The report as read is herewith presented and becomes a part of these minutes:

Report of the Secretary

The active paid-up memberships in the Society are distributed as shown below:

	Individual	Company
Washington, D. C.	5	
Arizona	3	
Arkansas	1	
California	83	
Colorado	82	1
Connecticut	2	
Delaware	2	1
Florida	1	
Idaho	32	
Illinois	13	
Iowa	3	
Kansas	3	
Louisiana	1	
Maryland	3	
Michigan	37	
Minnesota	10	
Missouri	1	
Montana	16	
Nebraska	8	
New Jersey	0	1
New Mexico	1	
New York	10	
Ohio	9	1
Oregon	6	
Pennsylvania	1	
South Dakota	7	
Utah	60	
Washington	7	
Wisconsin	2	
Wyoming	4	
Canada	30	2
England	1	
Belgium	1	
Denmark	4	
Ireland	2	
Uruguay	2	1
Netherlands	1	
Sweden	1	
Haiti	1	
Hawaii	1	
Mexico	1	
Spain	1	
	459	7
Total paid membership	466	

These figures show a gain of 64 members since the Seventh General Meeting.

The 1952 Proceedings were distributed to the membership in 1953 starting in late February. As of December 31, 1953, 235 of the 1952 Proceedings remained in the Secretary's office which, coincidentally is the same number of 1950 Proceedings which remained on December 31, 1950.

The inventory of recent regional and general meeting proceedings as of December 31, 1953, follows:

1949 Eastern Regional Proceedings	64
1950 General Meeting Proceedings	182
1951 Eastern Regional Proceedings	25
1952 General Meeting Proceedings	235
1953 Eastern Regional Proceedings	58

The office of the Secretary has continued an exchange of publications and information with many organizations both foreign and domestic. All this information is on file or in the library, thus available to the membership.

Respectfully submitted,
JAMES H. FISCHER, Secretary

Upon motion by J. R. Douglass, seconded by B. E. Easton and unanimously carried, the Report of the Secretary was accepted as read and ordered placed on file.

The chairman then requested that the Report of the Treasurer be read. The report as read is herewith presented and becomes a part of these minutes:

Report of Treasurer

Herewith is submitted the Treasurer's report covering the two-year period, January 1, 1952, through December 31, 1953:

Receipts

Beet Sugar Development Foundation	$ 7,000.00
Book Sales	1,634.09
Postage	71.00
Reprint Charges	943.00
Membership Dues (Includes $200 from Canadian Sugar Factories Limited and $500 Western States Machine Co.	3,093.50
Page Overage	660.00
Registration, Banquet ticket sales and Abstracts	3,316.50
(January 1, 1952-Dec. 31, 1953) Total Receipts	$16,718.09
Balance January 1, 1952	4,457.32
Total Balance and Receipts	$21,175.41

Disbursements

Meeting Expense (Banquet, Room Rent, Etc.)	$ 3,073.72
Printing, Engraving, Binding and Editing of Proceedings	9,702.14
Reprints	1,000.14
Postage and Express	568.63
General Office Expense	550.59
Total Disbursements	$14,895.22
Balance on Hand, January 1, 1954	$ 6,280.19

Respectfully submitted,
JAMES H. FISCHER, Treasurer

Upon motion by Mr. Andrews, seconded by Mr. Douglass, the Treasurer's Report as read was unanimously accepted and ordered placed on file.

The chairman then requested that a report of the Resolutions Committee be given. Upon motion by Dr. Brewbaker, seconded by Mr. Armer, the Report of the Resolutions Committee, as presented below, was unanimously accepted and herewith becomes a part of these minutes.

Report of the Resolutions Committee

The success of the 1954 General Meeting of The American Society of Sugar Beet Technologists is due to the efforts of those people who cooperated and who put forth an effort over and above their normal duties.

Be it resolved, therefore, that a vote of appreciation be given all those who have contributed of their time and efforts to make this Eighth General Meeting an outstanding success, with special recognition to the following:

President, Charles E. Cormany, for his unselfish devotion to the affairs of the Society and for his invaluable assistance in formulating the program of the 1954 meeting.

Secretary-Treasurer, James H. Fischer, for his services which involved detail and responsibility of the highest order.

Phillip B. Smith for his invaluable assistance as Chairman of the General Sessions and as a member of the General Arrangements and Publications Committees.

Holger Figge for his diligent efforts as Chairman of the General Arrangements Committee.

Thomas Hornsby Ferril for capable handling of publicity and display material.

Arnold A. Mast, Chairman of the Nominating Committee, who successfully achieved the difficult task of selecting nominees for office during the 1954-55 biennium.

Wilford Cannon, Chairman of the Awards Committee, whose mature judgment so adequately recognized the achievements of awards recipients.

Herbert L. Bush, Chairman of the Registration Committee, whose many duties in relation to the infinite detail of the registration formalities were so effectively concluded.

Austin Armer, who as General Program Chairman, provided capable leadership and an effective organization so largely responsible for the success of this meeting; also the following section chairmen for activating this program: Section A, F. J. Hills; Section B, Harold L. Kohls; Section C, Orin A. Hills; Section D, Read A. Wilkinson; Section E, R. S. Gaddie; and Section F, Robert H. Cotton. Guest speakers, Alex Dreier, National Broadcasting Company; Martin Weiss, U. S. Department of Agriculture; Henry B. Hass, Sugar Research Foundation; David Hamil, Speaker of the House, State of Colorado; William E. Morgan, President, Colorado A & M College, and R. G. Gustavson, Resources for the Future.

The American Crystal Sugar Company, The Great Western Sugar Company, Holly Sugar Corporation, National Sugar Manufacturing Company, Silver Engineering Works, Stearns-Roger Manufacturing Company and the St. Regis Sales Corporation Division of St. Regis Paper Company for generous financial support and other assistance in connection with the arrangements and entertainment during the course of the meetings.

The Denver Convention and Visitors Bureau for assistance in arranging for this meeting and for the conduct of registration.

The management of the Hotel Shirley-Savoy for its excellent cooperation and to the many employees for pleasant and courteous services.

The Beet Sugar Development Foundation for financial subsidy in excess of $7,000 for publication of the 1952 Proceedings, in addition to the valuable services of James H. Fischer as Secretary-Treasurer of the Society.

The Western States Machinery Corporation and the Canadian Sugar Factories, Limited, for substantial financial assistance in connection with the publication of the 1952 Proceedings.

Be it further resolved that The American Society of Sugar Beet Technologists pay tribute to the following esteemed members whose death occurred during the current biennium: D. J. Roach, W. W. Robbins, John E. Clark, E. Q. Marsing, Bert McCulloch and Otto Wegner. For these men, an appropriate in memoriam will appear in the Proceedings of this meeting.

The chairman then requested that the chairman of the nominating committee report the results of the election. Mr. Mast reported that the following had been duly elected to serve during the biennium 1954-55 or until succeeded: President, P. B. Smith; Vice President, F. V. Owen; Secretary-Treasurer, James H. Fischer; Advisory Council—West Coast Area, R. J. Tingley, Sam C. Campbell; Intermountain Area, Vernal Jensen, Ford T. Scalley; Eastern Slope Area, C. W. Doxtator, J. O. Gaskill, J. R. Mason; Eastern U. S. Area, M. G. Frakes, Grant Nichol; Eastern Canadian Area, B. E. Easton; Western Canadian Area, Frank R. Taylor; At Large, H. P. H. Johnson, C. H. Wadleigh.

The chairman then opened the meeting to invitations for the 1956 General Meeting. After listening to several invitations, a motion was presented, seconded, and unanimously carried, accepting San Francisco, California, as the place for the Ninth General Meeting on a date and at a place to be determined by the Executive Committee and Advisory Council through an appointed Local Arrangements Committee.

There being no further business, the meeting was declared adjourned at 4:15 p.m.

In Memoriam

Long in the memory of the beet sugar industry of North America will be those who have preceded us and have passed to their eternal rest. We who must fill their stations cannot refrain from proclaiming their deserved glory. The prestige of our industry, the stature of our Society, and our association with the economy of American Industry, are founded upon their foresight, integrity, and abilities.

Our way of life has been, and ever shall be, an evolution of new ideas, new processes, and new methods. So was life to these we here pay homage. Their persistence against odds of mountainous proportions lifted us to the plateau from which we gaze toward greater horizons. Their inspiration is a challenge to each one of us. May the memory of these be ever before us as a beacon directing us to visions incomprehensible. May they rest in peace.

David J. Roach
Wilford William Robbins
John E. Clark
Earl Q. Marsing
Bert O. McCulloch
Otto W. Wegner

Meritorious Service Award

These awards were presented at the Eighth General Meeting of the American Society of Sugar Beet Technologists to those who have been outstanding in promoting the objectives of this organization and who have been active in its affairs. The Society appreciates their outstanding efforts and wishes to acknowledge the important role each has played.

EUBANKS CARSNER

Dr. Eubanks Carsner's interest in sugar beets began in 1917 at which time he entered the service of the U. S. Department of Agriculture to investigate the cause and controls of curly top of the sugar beet. He was first stationed at Spreckels, California, until 1919, at which time, the base of operations for curly top investigations was transferred to Riverside, California. Through the joint efforts of Dr. Carsner, Mr. Stahl, and later Dr. Pack, the initial lot of commercial curly top resistant beet seed was developed. This variety was known as US 1 and became available in 1929. The value of his accomplishments was recognized and the work of curly top was extensively expanded and reorganized to include an effective program at Salt Lake City, Utah. Prior to his retirement, he was directing sugar beet investigations at field stations located in Utah, Idaho, California, and Oregon.

Dr. Carsner was born in San Antonio, Texas, on July 19, 1891. His early youth was spent in Victoria, Texas, where he attended elementary and high school. He was graduated from the University of Texas in 1912. After a year of teaching botany and chemistry in the Amarillo High School, Amarillo, Texas, he went to the University of Wisconsin, Madison, Wisconsin, for advanced study. He majored in plant pathology and received the M.S. degree in 1914 and the Ph.D. degree in 1917.

Dr. Carsner has now officially retired from the service with the U. S. Department of Agriculture but is being retained with the department on a part time basis as an advisor.

GEOFFREY S. CHILDS

Mr. Geoffrey S. Childs' interest in sugar beets began in 1934 when he came to Michigan and assumed direction of the activities of the Michigan Sugar Company as its vice president. In 1940, he became president of the company and in 1944 was elected president of the Farmers & Manufacturers Beet Sugar Association, a position he has held without interruption. Under his guidance, cooperation between companies in the eastern beet producing area has been brought to its highest point in history. He has been a leader in encouraging research and the development of new techniques for strengthening the industry. He has had a keen interest in the accomplishments of the American Society of Sugar Beet Technologists.

Mr. Childs was born in Media, Pennsylvania, and received his early education at Bryn Atahyn Academy in Bryn Atahyn, Pennsylvania. He graduated from New York University and from 1913 to 1926 was associated with the Alexander Hamilton Institute of New York as staff secretary

and later office manager. In 1926, he joined the Pitcairan Aviation, Inc., and was executive vice president at the time the airline was sold to what is now Eastern Airlines.

Between this time and his association with the beet sugar industry he remained in the aviation field as vice president of the Autogiro Company of America.

Mr. Childs is currently president of both the Michigan Sugar Company and the Farmers and Manufacturers Beet Sugar Association.

J. EARL COKE

Mr. J. Earl Coke's interest in sugar beets actually began while he was serving as assistant county agent in San Luis Obispo County, California. This interest became more keen when he became extension specialist in agronomy at the University of California. In 1935, he became associated with the Spreckels Sugar Company, San Francisco, California, and at the time he left this company in 1949 was vice president. During these years he obtained firsthand knowledge about the problems of the sugar beet grower and industry.

He has been extremely active in the affairs of the Society being part of the organization when it was formally developed as a Society. He served as chairman of innumerable committees, was vice president during the 1938-39 biennium and was president during the 1940-41 biennium.

Before assuming his current appointment as Assistant Secretary of Agriculture, Mr. Coke was director of California's extension service. In such capacity, then as now, he has stressed the importance of bringing agricultural services to the farmers to serve their greatly varied needs.

Mr. Coke was born on a dairy farm near Downey, California, on May 28, 1900. He attended high school at Ontario, California, and graduated in agriculture from the University of California in 1923.

Mr. Coke is presently Assistant Secretary of Agriculture under Mr. Ezra Taft Benson.

GEORGE H. COONS

Dr. George H. Coons' first experience with sugar beets was in 1899 when he grew a prize-winning quarter acre in a contest sponsored by the Illinois Sugar Refining Company of Pekin, Illinois. Dr. Coons' serious concern with sugar beets came while as a plant pathologist at the Michigan Agricultural Experiment Station where he did troubleshooting for the Michigan beet sugar factories whose crops were being seriously ruined by black root and leaf spot diseases. About 1920 he commenced research on sugar beet diseases and their control by seed treatment and disease resistance breeding. In 1924, he was loaned to the Bureau of Plant Industry Soils and Agricultural Engineering to initiate the research program of breeding varieties of sugar beets resistant to curly top and leaf spot. He returned to Michigan State College as plant pathologist on a half-time basis with the Bureau until 1929 when he left to become principal pathologist in charge of sugar beet research projects in the Division of Sugar Plant Investigations.

Dr. Coons was born in Bloomington, Illinois, November 2, 1885. He received his A.B. degree at the University of Illinois in 1908, his A.M. at the University of Nebraska in 1911 and his Ph.D. at the University of Michigan in 1915. He has been very active in the affairs of the Society since it was officially organized and served as the chairman of numerous committees, being vice president of the Society during the 1950-51 biennium.

After directing the sugar beet projects of the Bureau of Plant Industry for twenty-three years, he left administrative work to conduct research particularly on virus yellows. He is currently principal pathologist for the Division of Sugar Plant Investigations.

R. H. COTTRELL

R. H. Cottrell's interest in the beet sugar industry began in the fall of 1916 when he entered the employ of the Great Western Sugar Company as juice-benchman at the Fort Collins factory. In the fall of 1917 he became an employee of the Amalgamated Sugar Company and has been with this company since with few interruptions. For two years he served as assistant general superintendent of the combined Amalgamated and American Crystal operations. One year was spent as principal economist of the sugar section of the AAA in Washington, D. C., during the initial administration of the Sugar Act. With the Amalgamated Sugar Company he has served as common laborer, benchman, chief chemist, general chemist, statistician, station man, general superintendent, and vice president.

Mr. Cottrell was born July 17, 1892, in the village of Rhinecliff, New York, and moved, at a young age, to Manhattan, Kansas, where his father was head of the department of agriculture in the state agricultural college. Mr. Cottrell graduated as a civil engineer from the Colorado Agricultural College at Fort Collins. He has been a member of the American Society of Sugar Beet Technologists since the period of its organization. He has served on numerous committees and has been active in the affairs of the Society. He has always been an advocate of agricultural progress and maintains a keen interest in the agencies of the U. S. Department of Agriculture, land grant colleges, experiment stations, and extension services that foster and promote agricultural progress.

Mr. Cottrell is currently vice president of the Amalgamated Sugar Company at Ogden, Utah.

HENRY W. DAHLBERG

Mr. Henry W. Dahlberg's interest in sugar beets began before graduating from the University of Minnesota where he spent two campaigns and an inter-campaign with the Spreckels Sugar Company at Salinas, California. In the summer of 1910 Mr. Dahlberg entered the employ of the Great Western Sugar Company as night chemist at the Sterling factory. He served the company as factory chief chemist, traveling chemist, and manager of the statistical department until 1920 when he became director of research. Mr. Dahlberg made several trips to Europe to study and thereby broaden his background and knowledge of the beet sugar industry and processes. In

1912, six months were spent in Europe at the sugar institute at Berlin. In each 1924 and 1925, several months were spent in Europe studying various phases of the barium process for recovery of sugar from molasses. In 1924, the direction of the agricultural research for the company was added to his duties. Again in 1934 further research studies were made in Europe and in 1948 another visit was made for the purpose of studying European agriculture and research work in several countries. He has been a member of the American Society of Sugar Beet Technologists since its organization, has served as member and chairman of numerous committees. He was vice president of the Society in 1948 and 1949.

Mr. Dahlberg is currently retired as director of research for the Great Western Sugar Company after nearly forty-three years of continuous service.

DAVID J. ROACH

Mr. David J. Roach's service with the beet sugar industry began in 1908 as a chemist. During his tenure with the beet sugar industry he acquired an intimate knowledge of sugar beet technology and agriculture marking him as a leader in industry to which he devoted his entire active career. His enthusiasm was responsible for the writing of a textbook "Technology of Beet Sugar Manufacture." No person, perhaps, understood both the agricultural and operating functions of the complex beet sugar industry better than Mr. Roach. His factory achievements were outstanding and his excellent work in reducing labor requirements in growing sugar beets through the early encouragement of the use of harvesting machines and the development of mechanical thinning machines have won wide and deserved recognition. To Mr. Roach life itself was pioneering. It was making do with the tools at hand, yet missing no slightest chance to acquire better ones. Lifelong observations made him an international authority on the use of water for irrigation and its place in the farming of western lands.

Mr. Roach was born of pioneer parents on a dry land ranch near Sedalia, Colorado. He was educated in a country school where he showed a definite interest in mathematics, chemistry, and science. Following these interests he graduated from Colorado A & M College in 1908.

Mr. Roach, now deceased, resigned as a director and executive vice president of the Great Western Sugar Company in 1952 after forty-four years of service. His friends will remember him as a giant in spirit who refused to let physical frailty keep him from vast achievement, whose knowledge, judgment, and uncompromising sense of fairness and integrity commended the very highest esteem by those with whom he came in contact.

DOUGLAS E. SCALLEY

Mr. Douglas E. Scalley's first contact with the beet sugar industry was in Lehi, Utah, where he was born. His first work in a sugar factory commenced at Mt. Clemens, Michigan, in 1902. In 1903, he started work for the Utah-Idaho Sugar Company at Garland, Utah, and was transferred to Sugar City, Idaho, when that plant was built. He was appointed superintendent of the Sugar City factory in 1917, became district superintendent

at Idaho Falls in 1920 and was transferred to Salt Lake City as general superintendent in 1922. He left the general office to return to Idaho Falls as district manager in 1926. Later he became general agricultural superintendent for the company, at which time, he became familiar with the necessity of research for the purpose of overcoming the ravages of curly top. He took a very active part in the formation of the Curly Top Resistance Breeding Committee, of which he was chairman for several years, and the West Coast Beet Seed Committee. In 1938, Mr. Scalley became vice president and general manager of the Utah-Idaho Sugar Company and in 1951 was given the additional duties of executive vice president.

Mr. Scalley received his education in the school system of Lehi, Utah. He was active in the organization of the American Society of Sugar Beet Technologists and has served on numerous Society committees. He has been on numerous committees formed for the purpose of improving the stature of the beet sugar industry in the United States. He has encouraged research by assisting in the procurement of appropriations for research.

Mr. Scalley is currently executive vice president and general manager of the Utah-Idaho Sugar Company and has completed fifty-one years of continuous service with that company.

ARTHUR A. SCHUPP

Arthur A. Schupp's interest in the beet sugar industry began in 1932 when he became one of the organizers of the Paulding Sugar Company, Paulding, Ohio. Prior to this date, he was interested in various automotive parts manufacturing companies. In 1933, the Farmers & Manufacturers Beet Sugar Association was organized and Mr. Schupp became its executive secretary. He has a keen appreciation of the importance of research in maintaining the prosperity of agriculture in this country and the well-being of its people and industries. Under his leadership, an outstanding program of agricultural research and technology has been developed with college, universities and experiment stations within the eastern sugar beet growing area as well as with the Division of Sugar Plant Investigations. He has been an active member and strong supporter of the American Society of Sugar Beet Technologists on a national and regional basis. His encouragement and support of the activities of the eastern regional section of the Society has been largely responsible for making the eastern regional group the strongest and most active section of the Society. His role has been significant as a member of the beet sugar industry advisory group which has developed and shared the sugar legislative program during the past twenty years.

Mr. Schupp was born and reared in Saginaw, Michigan, and received his college training in automotive engineering at the University of Michigan, Ann Arbor, Michigan. During World War I, he served as a first lieutenant in the aviation branch, signal corps.

Mr. Schupp is currently serving as executive secretary of the Farmers & Manufacturers Beet Sugar Association in Saginaw, Michigan. His contribution to the beet sugar industry of this country and particularly to the eastern sugar beet area, is most significant.

HERMAN EDUARD ZITKOWSKI

Herman Eduard Zitkowski's interest in sugar beets began in Norfolk, Nebraska, as an interpreter for a German Steffens expert in 1895. He became bench chemist at this factory in 1897 and in 1899, moved to Kalamazoo, Michigan, as assistant chemist for the Kalamazoo Sugar Company. Between 1900 and 1902, he was chief chemist, agriculturist, and assistant superintendent for the Detroit Sugar Company in Rochester, Michigan. Between 1903 and 1905, he was assistant superintendent for the National Sugar Manufacturing Company in Sugar City, Colorado. From 1906 to 1910, he served as chief chemist, in a general capacity and superintendent at the Las Animas factory, all with the American Beet Sugar Company. Between 1914 and 1925, he was general chemist for the same company, maintaining headquarters at Rocky Ford, Colorado, through 1918, when he moved to Oxnard, California, and then to the general office in Denver, Colorado, in 1924. During this latter period, he was instrumental in interesting the company's executive officers in negotiations for land acquisition and purchase of the processing plants at Mason City, Iowa, Chaska, Minnesota, and of the Red River Valley Sugar Company. In 1925, he became general superintendent but continued to serve the company as general chemist and general agriculturist. In 1932, he became general manager, in 1934 was elected vice president, continuing as general manager until 1949 when he became general consultant for the company, now known as the American Crystal Sugar Company.

Mr. Zitkowski was born in Culm, Germany, in 1880 and migrated to the United States with his family in 1892, settling in Norfolk, Nebraska. His first six years of education were in a German grade school. He was further educated in a Lutheran parochial school, then grade and high school in Norfolk, Nebraska. He attended Fremont Normal School, Midland College, at Fremont, Nebraska, and received a Master of Science degree from Valparaiso University, Valparaiso, Indiana.

Mr. Zitkowski is currently on the board of directors for the American Crystal Sugar Company and serves as general consultant. To many he is known as the dean of the beet sugar industry in the United States.

Distinguished Service Awards
Forty Year Veterans

These awards were presented at the Eighth General Meeting to those who have completed forty years of faithful service with the beet sugar indusry of America. The Society proudly pays honor to each of these awardees for the important part each has played in the development of the industry.

AVERY A. CLARK

Avery A. Clark graduated from Yale University in June 1909, having majored in chemistry and engineering. He entered the employ of the Great Western Sugar Company in October of the same year as a bench chemist in the laboratory of the Loveland factory.

Having served the intervening time as station operator, foreman and assistant superintendent, Mr. Clark was transferred to the Eaton, Colorado, plant in 1920 as superintendent. He served the company as plant superintendant at five different factories over a period of the next twenty years. In 1940, he was promoted to district superintendent of the company's six eastern division plants.

In 1942, Mr. Clark was appointed vice president and general superintendent, which position he held until 1951. Since that date he has acted as assistant to the president, devoting his attention primarily to improvements in operation practices and equipment connected with factory procedure. He has taken an active interest in the development of ways and means for solving the beet sugar factory waste disposal problem, toward which end considerable progress has been made in the recent past.

THOMAS HEATH

Mr. Thomas Heath was born January 22, 1894. He started work with the beet sugar industry at Bay City, Michigan, in 1909. He left the beet sugar industry between 1912 and 1914, returning to Bay City as battery man, Steffens man and filter expert. In 1917, he moved to Mason City, Iowa, and stayed until 1919, at which time, he moved to Worland, Wyoming, thence to Cornish, Utah, as assistant superintendent. In 1921, he left Cornish to assume the position as superintendent of a factory at Worland, Wyoming, a plant then owned by the Wyoming Sugar Company. When the Holly Sugar Corporation bought the Worland factory in 1925, Mr. Heath was transferred to Preston, Idaho, as general manager and plant superintendent. At the present time, he is vice president and general manager of the Franklin County Sugar Company, Preston, Idaho.

Mr. Heath has been active in the political affairs of the State of Idaho, having served four years as state senator in Idaho and is at present time the Idaho state senator from Franklin County.

GEORGE EDWARD HOGAN

Mr. George Edward Hogan was born in Kaukauna, Wisconsin, on February 12, 1892. He started his work in the beet sugar industry with the National Sugar Manufacturing Company, Sugar City, Colorado, on May 15, 1913. In 1916, shortly after he became associated with the National Sugar Manufacturing Company, he became an officer of the Company, serving as treasurer. During World War I, he was compelled to accept a leave of abscence for service in the United States Army. In 1926, Mr. Hogan was given the duty of local manager in which capacity he served until 1943, at which time, he was elected a director and vice president. He is currently serving in the latter two capacities for the National Sugar Manufacturing Company.

R. NEWTON MILLER

R. Newton Miller started work in the beet sugar industry with the then Holly Sugar Company at Holly, Colorado, March 27, 1906, as mail clerk. Shortly thereafter, he was promoted to bookkeeper and after the company's offices were moved to Denver, was given the position of cashier.

In 1920, he was transferred temporarily to Grand Junction, Colorado, in charge of the Grand Junction and Delta offices, remaining there during the period the Delta factory was being constructed. Two years later, he returned to the Denver office as cashier.

Several years later, he was advanced to assistant secretary and assistant treasurer and was charged with all real property records of the corporation, all taxes relating thereto, and the preparation of monthly financial statements. His duties were then expaned to include projection of the estimated financial requirements of the corporation. In 1933 and 1934, he temporarily was given the duties of the secretary, due to the illness and eventual death of the secretary. He was then charged with the placing of the corporation's insurance and relieved of the task of preparing monthly financial statements and handling property tax matters.

Mr. Miller is currently assistant secretary and assistant treasurer of the corporation, in charge of all real property records, including titles thereto, all phases of insurance, financial budgeting, and arrangements pertaining to the corporation's cash, and bank accounts relating thereto.

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